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NANSEN'S WAYMARKS TO THE NORTH POLE.

By W. F. HUME, D.Sc.

FOR many years a small, but happily increasing, group of zoologists and geologists has maintained the importance of studying the microscopic forms of life, believing that, even apart from their intrinsic interest, they will eventually lend material aid to the solution of many keenly-discussed problems. Recent events have tended greatly to justify this position, and it will be our present aim to show how minute plants have been used as arguments in connection with Polar exploration. In 1892, Dr. Nansen, whose successful return to Europe has caused so great a sensation, submitted to the Royal Geographical Society his reasons for believing that the North Pole could be reached if the methods he proposed were carried out. He argued, firstly, that the great Polar currents run southward between Greenland and Spitzbergen; whereas, on the Siberian side, a constant current of fresh water is running northward, turning north-westward at the New Siberian Islands, probably crossing the Pole, and, eventually, forming the southward current previously mentioned. Many facts were adduced in support of his contention. Thus, Siberian larch and red spruce every year reach the coast of Greenland, and supply the wood used by the Esquimaux in the construction of their boats, sledges, etc.; these relics being also, as Nansen remarks, found in the sea north of Spitzbergen among the ice-floes carried southward from the unknown North.

On one of his previous expeditions to Greenland, Nansen collected many samples of dust from the surface of the snow on the ice-floes between Iceland and Greenland, and was much interested in the Diatomaceæ found in some of these. The Diatomaceæ are minute unicellular plants, each cell being inclosed in a small case, or frustule, composed of siliceous material. This casing consists of two valves or plates, one overlapping the other, somewhat after the manner of the two parts of a pill-box. The surfaces of these valves often appear beautifully ornamented, due to the presence of depressions, lying in the interspaces of an elevated reticulation. The diameter of the plates is usually less than one two-hundredths of an inch, so that they require the highest powers of the microscope for their study.

Nansen submitted his specimens to Prof. Cleve, of Upsala, who, after identifying sixteen species and varieties, reported on them as follows:—"The diatom flora of this dust is quite peculiar, and different from that of all the many thousands of samples which I have examined with the exception of one, with which it shows the most complete congruity, viz., a sample which was collected by Kjellman (during the *Vega* expedition) on the floe-ice at Cape Wankarema, near Behring Straits. The species and the varieties are exactly the same in both samples. It is quite remarkable that the diatom flora on ice-floes near Behring Sound and on the east coast of Greenland are so completely alike and so unlike all others. It indicates that there is an open communication between the seas east of Greenland and north of Asia." Nansen adds: "All these" (referring to his own specimens) "were also found at Cape Wankarema, *twelve of them being only known from there, and from nowhere else in the whole world*; and that though the diatom flora of the Kara Sea, Franz Josef Land, Spitzbergen, and Greenland has also been partly examined." All through his paper Nansen showed his keen appreciation of little things. The minerals in the dust were also examined, no less than twenty varieties being recognized by Törnbohm, who exclaims: "Can it be possible that the terrestrial portions of the dust originate from Northern Siberia? that it is partly mud carried into the sea by the great Siberian rivers? The great variety of minerals contained in the dust seem to me to indicate that it originates from an extensive land region, and thus it seems most natural to think of Northern Siberia." Again, much pumice, belonging to a group of rocks known as the Andesites, has been found on the shores of Spitzbergen and Greenland, altogether dissimilar from those of any volcanic region in the Atlantic Ocean, but very possibly derived from the Andesitic volcanic regions near the Behring Sea.

Thus, relying on some driftwood, minute minerals, and microscopic plants—backed, it is true, by wider considerations—did this gallant explorer trust himself to his little vessel, and, joining the ice-floes near the New Siberian Islands, await in the *Fram* the fulfilment of his expectations. What has been achieved is known of all men; but when the results come to be weighed in the balance, let us hope that the humble plant-helpers will not be forgotten.

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SIXTY YEARS OF ASTRONOMICAL RESEARCH.

By Miss Agnes M. Clerke,

Authoress of "The System of the Stars," and "A Popular History of Astronomy during the Nineteenth Century," &c., &c.

THE progress of astronomy since the accession of the reigning sovereign has been, on one side, a development; on the other, a metamorphosis. While the traditional methods have been improved, and traditional aims pursued with ever-increasing diligence, novel methods have come into use—novel methods of such transforming power that the science has, in a measure, changed its aspect and attitude. Sixty years ago it stood apart, in close alliance with mathematics. Now it appeals for aid to chemistry and optics, to electrical, thermal, and molecular investigations. Every new fact ascertained in a laboratory has a bearing upon some cosmical problem; every well-grounded theory of matter and force finds its application in the heavens. These intricate relations possess a significance as yet imperfectly apprehended; they may lead to generalisations of a higher order than any so far attained. Their establishment is the cardinal event in recent astronomical history.

Astrophysics took its rise in 1851 from Schwabe's discovery of the sunspot period; for it was quickly perceived that the magnetism of the earth, including auroral displays, obeyed an identical law of change. Thus, terrestrial phenomena acquired an universal import, and became affiliated to cosmical vicissitudes. The chemical interpretation given by Kirchhoff to the hieroglyphics of the solar spectrum drew the connecting bonds closer. He announced to the Berlin Academy of Sciences, December 15th, 1859, the presence in the sun of sodium, iron, magnesium, calcium, and some other familiar metals. The evidence warranting these identifications was the agreement of certain "Fraunhofer lines" with the individual rays given out by the glowing vapours of the substances in question, coupled with the fruitful root-principle of the correlation of emission and absorption. The position of each isolated ray in the dispersed light of a heavenly body was thus shown to be indicative of its constitution, and the *impossible*—as Comte had declared acquaintance with such facts to be—was achieved.

The science of astrochemistry developed rapidly. About thirty-six elements, including hydrogen and carbon, have been recognized as common to sun and earth, and those missing need not be supposed absent. Three among them—antimony, bismuth, and mercury, all heavy metals—early declared themselves in the red stars, Aldebaran and Betelgeux; and some fine lines belonging to oxygen—a long-sought and evasive substance—have apparently just been picked out by Runge and Paschen from Mr. Higgs's solar spectral photographs. Undetermined lines, however, still abound in celestial spectra, to an extent, it might almost have been thought two years ago, seriously compromising the prospects of advancing knowledge. But Prof. Ramsay's enfranchisement from its millennial prison in a Norwegian mineral of the solar gas helium, has effectually dissipated these misgivings. Its highly complex spectrum figures bright in the solar chromosphere, in nebulæ, and temporary stars; dark, in a restricted class of white orbs, a complete battalion of which are arrayed in the constellation Orion. The chief nebular constituent has not, so far, been "unearthed"; nor "coronium," a gas probably lighter than hydrogen, which pervades the solar halo. They may, nevertheless, be found any day hibernating in the earth's crust.

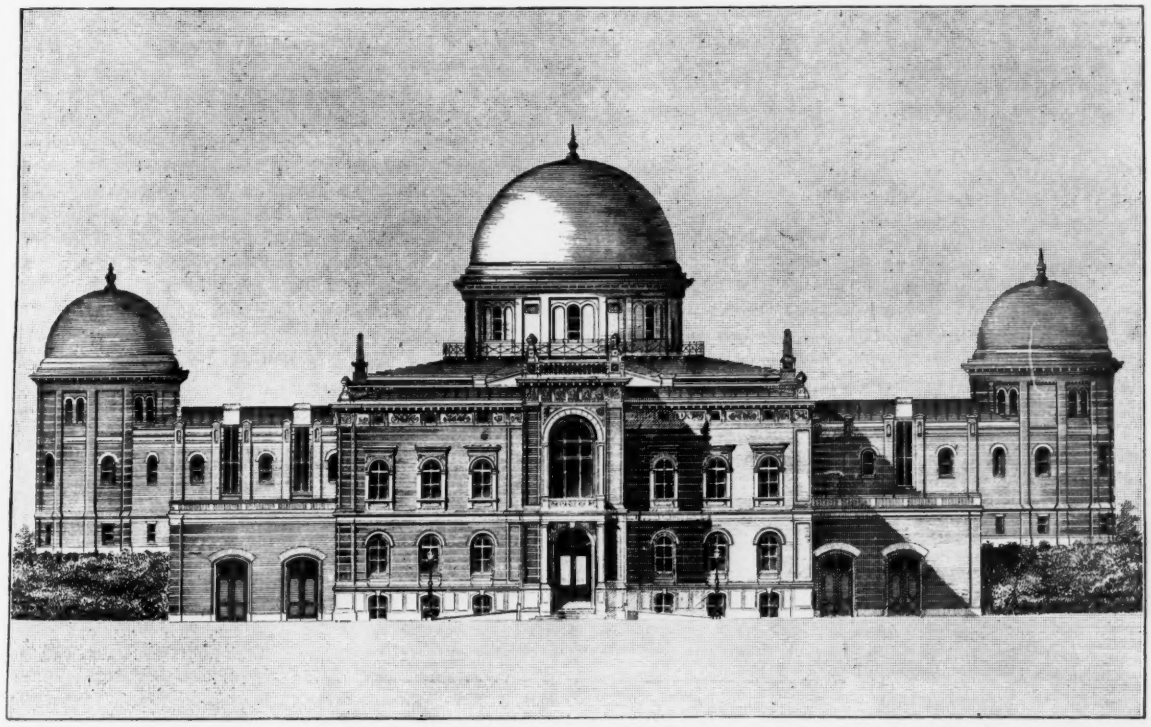
The stars were, in 1863, brought by Dr. Huggins and Prof. W. A. Miller within the scope of Kirchhoff's conclusions. Their chemistry proved to be generically the same with that of the sun, although with decided specific differences. They were divided by Father Secchi into four spectral orders; and his classification has been in the main adhered to by Prof. Vogel, who added the "rationalising" idea of decline with increasing age, from the culminating splendour of the Sirian type, through a solar stage, to the waning fires of red stars showing banded spectra. His scheme of decay was enlarged into a scheme of development by Mr. Lockyer, who begins at the beginning with the nebulæ; but it is unlikely that time is the sole factor in producing the observed varieties of sidereal species.

Dr. Huggins began his investigations of nebular spectra on August 1st, 1864. The first he looked at consisted of one bright and two fainter green rays, the most refrangible being the "F" of hydrogen. He had selected for examination the "planetary" in Draco, and all nebulæ of that kind, as well as those of irregular shape like the great formation in Orion, are of gaseous constitution. But he soon found that most nebulæ, and notably the vast ellipse in Andromeda, give a continuous spectrum such as might be derived from distant star-clusters. The manner of their distribution separates them emphatically, nevertheless, both from gaseous objects and from true clusters, the latter two classes belonging characteristically to the zone of the Milky Way, while ordinary nebulæ gather towards its poles. This architectonic relation proves them to make an integral part of the galactic system, and is one among many reasons elicited by modern research for rejecting the claim to autonomy as "island universes" long ago set up for them by Kant.

The rapid progress of astronomy in our time along the old no less than the new lines of research, has been largely due to its adoption of photography as an ally. The services which this wonderful art has proved capable of rendering have distanced hope. The staying power of the chemical plate, its faculty of waiting upon time and integrating infinitesimal impressions, has led to the partial abdication in its favour of the human eye. It has the further prerogatives of sensibility to *invisible* light, of swiftness in procedure, and of affording permanent and absolutely truthful records. There is no imagination behind it. The addition of these powers to astronomical resources has effected a revolution unique in the history of science, and still actively advancing. Its consequences are unexhausted, and apparently inexhaustible.

Celestial photography is predominantly employed in four departments of inquiry: in direct portraiture, in the discovery of new objects, in star-charting, and in the delineation of spectra and spectral forms. The various results can here be no more than barely indicated. Warren de la Rue was the earliest promoter in this country of solar and lunar photography. With his "photoheliograph" the daily registration of sunspots was begun at Kew in 1858; and the same instrument served, during the

Spanish eclipse of July 18th, 1860, to depict the "red prominences," the mere display of which, as progressively covered on one side and uncovered on the other by the moving globe of the moon, sufficed to demonstrate their solar dependence. A daguerrotype of the corona of 1851 is still extant; and coronal photography has grown to be an art in itself, practised, weather permitting, with added success, each time that the mysterious solar nimbus starts into view from behind the interposing moon. It imprinted itself with particular effectiveness on plates exposed by Sir George Baden Powell at Novaya Zemlya, August 9th, 1896. The instructive details of its intimate structure can be studied only by means of such authentic records. A photograph of the "reversing layer," fortunately secured on the same occasion by Mr. Shackleton, locates the chief seat of the Fraunhofer absorption in a shallow stratum



VIENNA OBSERVATORY: AN IDEAL ESTABLISHMENT SUCH AS WE MIGHT HAVE, BUT HAVE NOT, IN ENGLAND.

near the photosphere. The phenomenon had been spectroscopically viewed as a flash of bright rays by Prof. Young in 1870.

Comets and nebulæ are slow in self-portraiture; which was, indeed, rendered practicable only by the invention of dry plates with their attendant facility for long exposures. Hence, the first comet successfully recorded was Tebbutt's in June, 1881; while some photographs of the great September comet of 1882, obtained by Mr. Allis at the Cape Observatory under Dr. Gill's supervision, started and exemplified two broad streams of laborious inquiry. Taken with a common portrait-lens, their perfection showed the advantages of the wide field of view and strong concentration of light afforded by that type of instrument; and the richness of their star-sprinkled backgrounds irresistibly suggested the use of the camera for the preparation of stellar charts and catalogues. No brilliant comet has appeared since 1882; but between 1892 and 1894 several minor apparitions were photographed by Prof. Barnard night after night, with the "Willard lens" of the Lick Observatory. The multiple nature and fibrous composition of their tails, imperceptible telescopically, came out strikingly upon his negatives, which testified besides to irregular effluxes of nebulous matter from the heads.

Dr. Henry Draper obtained a promising photograph of the Orion nebula, September 30th, 1880; and Dr. Common's classic pictures of the same object, by which the future of nebular self-delineation was assured, followed in 1883. Dr. Roberts next entered a field in which he has won signal success. A plate exposed for three hours, with his twenty-inch reflector, October 1st, 1888, disclosed the Andromeda nebula in its true annular or spiral shape—furrowed, as it were, by the action of some mighty unknown force. The same formative law is operative in many sidereal bodies. Whorled nebulæ were recognized visually, with the Rosse six-foot reflector, in 1845; their mode of structure has been ratified and extended by the camera. Even the immense southern aggregations of stars and nebulæ known as the Magellanic Clouds, appear, from Mr. Russell's photographs, to have their parts disposed along helical lines. This is wonderful and inexplicable.

Prof. Barnard undertook in 1889 the task of photographing the Milky Way. It is not an easy one. The star-clouds and star-sprays constituting it can neither be seen nor depicted with an ordinary telescope. They must be taken in the mass, not bit by bit. The Willard lens, however, proved equal to the occasion, and a series of astonishing galactic views were produced, in which lucid piles and drifts of star-dust are singularly interrupted by black chasms, cracks, and vacuities.

The plan of multiple exposures, introduced by Dr.

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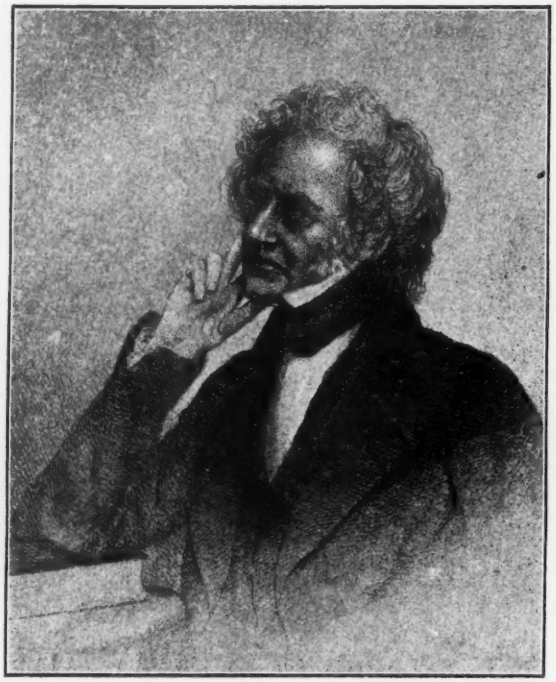
Roberts about 1890, has added greatly to the powers of nebular photography. By its means, Dr. Gill obtained, more than a year ago, in twenty-four hours divided among several nights, a grand picture of the "Keyhole" nebula in Argo. Its extent and intensity are wholly due to the *patience* of the sensitive plate, for the object is but feebly actinic. The absence from it of a large, trident-shaped structure, conspicuous in Sir John Herschel's drawing, indicates a change which, although startling, cannot readily be explained away. It would not, if real, be unexampled. Other nebulæ have been found to vary in light, notably Hind's in Taurus, which, after many vicissitudes, was completely invisible with the Lick thirty-six-inch refractor in 1895.

The eye sees at once, or not at all; the camera sees by degrees: hence its effectiveness as an engine of discovery. It brings into cognizance the contents of depths of space unsounded by the telescope, as well as objects hidden by their intrinsic faintness, or by the quality of their radiations. On November 16 h, 1885, a short, curved, nebulous train attached to the star Maia, unexpectedly emerged to view in a photograph of the Pleiades taken by the MM. Henry; and further investigations by them and Dr. Roberts showed the whole cluster to be largely involved in cosmic fog. Vast chaotic masses of the same kind, involving stars in the Milky Way, have since declared themselves on Barnard's and Max Wolf's negatives; and Prof. W. H. Pickering, using a portrait-lens of insignificant dimensions, secured in 1889, from the summit of Wilson's Peak in California, records of a stupendous spiral, enveloping the major part of Orion, and following a line of incurvation, as if towards a nucleus in the shining nebula attached to the Giant's Sword.



Sir John Herschel.

The first photographic detection of a comet fell to the share of Prof. Barnard, October 12th, 1892. Had it not been for the intervention of the Willard lens, the object might have altogether escaped notice. It proved to have a period of six years, and seemed to have exhausted its vitality. In asteroidal discovery by the same versatile method, Dr. Max Wolf led the way. With the exceptions of the original four—Ceres, Juno, Pallas, and Vesta—all the minor planets now known, to the number of nearly four hundred and forty, have been introduced to our acquaintance during the Queen's reign. They were captured telescopically by a laborious comparison of star-maps, until December 22nd, 1891, when No. 323 imprinted on a Heidelberg negative a trail, marking and measuring its motion. The hint was at once taken, and the photographic registration of these little bodies progresses apace. The supply of them seems unlimited, and they are far more troublesome to keep than to catch; so that the question arises whether they are worth the cost of computation. But astronomers are reluctant to throw back into the sea of space any fish that comes to their nets.

The only photographic star-catalogue as yet existing is Dr. Gill's "Cape Durchmusterung," the first volume of which, containing one hundred and fifty-two thousand five hundred entries, has just been issued from the press. In all, about three hundred and fifty thousand stars, measured from the Cape plates by Prof. Kapteyn, are enrolled in this comprehensive survey. Its construction, prompted by the comet pictures of 1882, was designed as a preliminary to a still greater work. On Dr. Gill's suggestion, an International Congress met at Paris in April, 1887, and decreed the construction of a photographic catalogue and chart which should accurately represent the state of the whole heavens at the close of the nineteenth century. This grandiose idea bids fair to be adequately realized. At seventeen observatories scattered over the globe, the necessary materials are in rapid course of accumulation. The catalogue will give the *exact* places of perhaps a million and a quarter stars. The longer-exposed chart-plates will record, by a current estimate, some twenty millions. These will not, however, be *booked*. They will be inscribed in an atlas consisting of copies on glass of the original negatives. Their identification at any future time will in this way be made possible. From the study of the wonderful mass of statistics thus provided, many curious discoveries may result; knowledge as to the laws of stellar distribution can, at any rate, hardly fail to be improved. It is true that difficulties in the way of determining photographic stellar magnitudes somewhat impair this prospect. Visual photometry has, by prolonged exertions—for which Harvard College is especially distinguished—been raised to a satisfactory degree of precision; but photographic photometry is still in the empirical stage. The rank of a star cannot yet be defined in terms of chemical action.

Perhaps the most important to astronomy of the varied faculties of the sensitive plate is its power of delineating, in full detail and with exquisite delicacy, the spectra of the heavenly bodies. It perceives the ultra-violet rays to which the eye is blind; it almost ignores air tremors; and it affords lasting records in lieu of fugitive glimpses. Dr. Huggins was a pioneer in the "spectrographic" art, which led him, in 1879, to the memorable discovery of the invisible section of the hydrogen-spectrum, as portrayed by absorption in the analyzed light of Sirius, Vega, and some other "white stars." The range of new lines thus unexpectedly revealed, form, with those previously known, a harmonic series bound together by a numerical relation known as "Balmer's Law"; and analogous series have since been recognized in the spectra of various substances, notably in that of helium. Their presence is of the utmost

significance as regards the nature of the ultimate particles of matter; and their first detection in the rays of inconceivably distant stars curiously illustrates the close mutual dependence of cosmical and terrestrial physics.

With the apparatus in use at Harvard College, star-spectra can be photographed by the score together; and as a result of these expeditious proceedings, the "Draper Catalogue" of ten thousand three hundred and fifty-one stars, referred to fifteen spectral subdivisions, appeared in 1890. At Potsdam, where the same kind of work was executed with a slit spectroscope instead of with an objective prism, a few bright stars were made the subjects of a stricter examination. Moreover, the main purpose of the scrutiny was not to ascertain their chemical and physical peculiarities, but to determine their motion.

Christian Doppler, of Prague, enounced in 1842 the principle of an alteration in the refrangibility of light emanating from a source retreating or advancing relatively to an observer. It is, indeed, tolerably obvious that the ethereal waves must be virtually lengthened in the first case, shortened in the second; and the rate, no less than the direction of radial movement, can be ascertained, as Fizeau showed in 1848, by measuring the displacements of lines, bright or dark, in the spectra of the moving bodies. Twenty years, however, elapsed before any attempt was made to realize the indicated method. It was reserved for Dr. Huggins, in 1868, to apply it practically to stars and nebulæ.

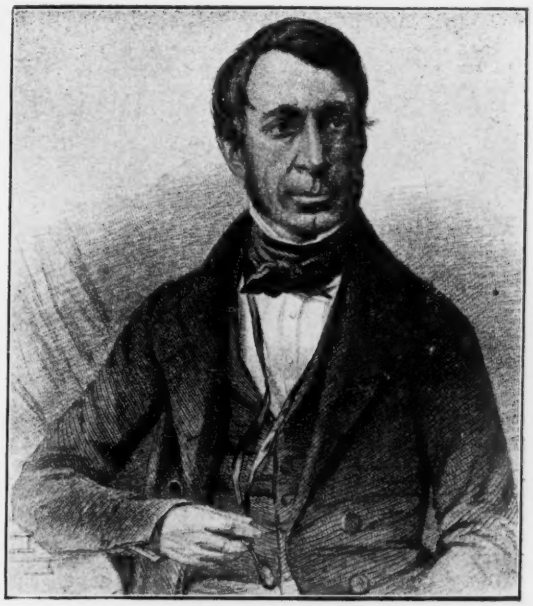
A fresh and incalculable impulse was thus given to sidereal science. Telescopically, bodies travelling in the line of sight appear stationary; but the spectroscope, by this exquisite mode of discernment, supplies the missing component of motion, irrespective both of distance and of time. Here, then, geometrical and physical inquiries meet on common ground, each furnishing data of comparable value for the mathematical treatment of problems in celestial mechanics. Without the aid of photography, however, no sufficient accuracy in this matter was possible. In estimating line-displacements the eye is continually baffled by atmospheric agitations, which the chemical retina, in the long run of, say, an hour's exposure, is enabled to ignore.

Dr. Vogel, Director of the Potsdam Observatory, ably seconded by Dr. Scheiner, initiated, in 1888, the spectrographic measurement of radial movements, and the details of his model investigation were published in 1892. An average rate of ten and a half miles a second was derived from fifty-one stars, of which Aldebaran, with a recession of thirty miles a second, was the most rapid. On the completion of a thirty-two-inch photographic refractor, lately ordered by Dr. Vogel, the inquiry can be extended to several hundred fainter stars; and materials will then at last be at hand for a really authentic determination of the sun's course through space, and of the speed with which it is pursued. No treatment of stellar *proper*—that is, telescopic—motions, avails to elicit, apart from doubtful assumptions, the latter element; but the general upshot of a large mass of recent work on the subject has been to shift the solar apex from the point where Herschel placed it in 1783, towards Lyra and the plane of the Milky Way. But the limits of uncertainty are, if anything, wider than they were left by Argelander's discussion in 1837.

The first evidences of motion in nebulæ were obtained by Prof. Keeler in 1890 from spectroscopic observations made visually with the great Lick equatorial. The light-grasp of the instrument, and the stillness of the air on Mount Hamilton, contributed, with his exceptional skill, to make his results trustworthy. They applied to ten planetaries, found to possess radial movements of at least the average stellar velocity. The thwartwise motion of nebulæ has yet to be detected. Their apparent fixity is doubtless due, in part to their remoteness, in part to inaccuracies in the places assigned to them.

The discovery of "spectroscopic binaries" is one of the most striking fruits of the line-of-sight method. Miss Maury's examination of the Harvard photographs showed, in 1889, that the lines in the spectrum of ζ Ursæ Majoris separate and close up again once in fifty-two days, obviously as a consequence of the orbital revolution in twice that time of a pair of suns. Soon afterwards, β Aurigæ was similarly decomposed, the spectral duplications taking place, however, on alternate days; and two unequal couples, with still shorter periods, have since been discovered at Harvard. Systems equally rapid are formed by the union of bright with dark components. They are recognized by the occurrence of periodical opposite displacements in the single spectrum of the obscurely attended star. Spica Virginis is of this kind. Its peculiar character was detected photographically at Potsdam. A number of variables belong to the same type, notably Algol, and other eclipsing stars. Less intelligibly, δ Cephei and its congeners, in which the law of light-change appears to exclude eclipses, range themselves unmistakably in the category. Some of these extraordinary couples circulate in a few hours, most likely with enormous velocities.

The combination of lucid with obscure, or partially obscure, masses appears to be a regular part of the cosmical scheme. The presence of dark stars in ordinary stellar systems is not unfrequently betrayed by their gravitational effects upon the movements of their bright fellows.

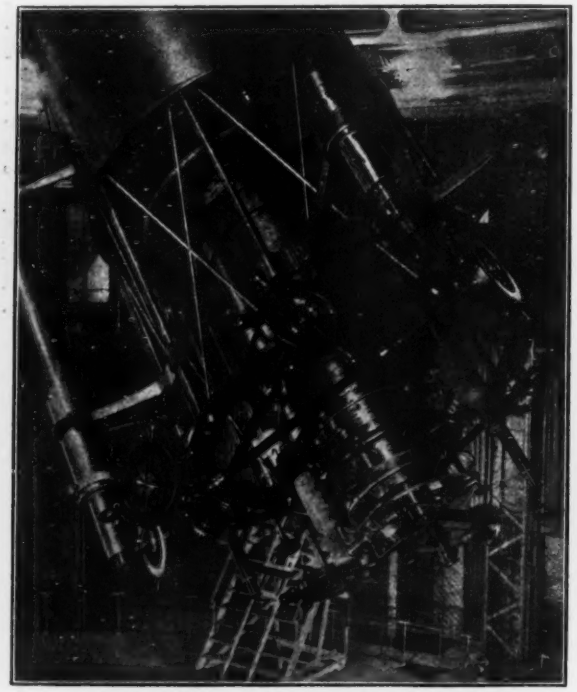


SIR GEORGE AIRY.

Examples are met with in ζ Cancri and 70 Ophiuchi. The dusky attendants, too, of Sirius and Procyon were predicted by Bessel as necessary to explain the undulating proper motions of the Dog Stars long before they were actually seen; the former, by Clark in 1862—the latter, probably, by Schaeberle in 1896. The "astronomy of the invisible," however, achieved its highest triumph in the

discovery of Neptune. The influence of an exterior planet had been more or less definitely *felt* through the perturbations of Uranus; but only such mathematical giants as Adams and Leverrier were competent to assign its place at a given epoch. Adams had the priority, but his indications were neglected until reinforced by those of his French competitor; and while a leisurely search was slowly progressing at Cambridge, the new planet was picked up, almost at the first glance, by Galle at Berlin, September 23rd, 1846. The possession of a fine star-map gave him, it should be added, a decisive advantage over Challis.

The earliest information regarding the spectrum of the solar prominences was secured during the Indian eclipse of August 18th, 1868. It proved to consist of a few bright lines of hydrogen and helium; and its discontinuous nature



Eyepiece End of the 36-inch Equatorial of the Lick Observatory.

enabled Janssen and Lockyer to realize the spectroscopic method of daylight observation at the edge of the sun, by means of which the chromosphere and its prodigious outlying flames have since been unintermittently studied. The forms spectroscopically viewed have of late been successfully photographed. The employment for this purpose, by Hale and Deslandres in 1891, of an apparatus with a double slit, marked the opening of a new chapter in solar physics. A single quality of light is thus effectively isolated; and both at Chicago and Paris the shadowed "K line" of calcium was chosen as the actinic agent. The same ray is emitted by faculæ, which, with its aid, can be photographed all over the sun's surface.

Since 1837, seven secondary bodies have been added to the planetary system. On October 10th, 1846, Mr. Lassell's famous two-foot speculum showed him Neptune's solitary moon, and, five years later, the two inner Uranian satellites. He espied, moreover, September 19th, 1848, simultaneously with W. C. Bond on the opposite shore of the Atlantic, Hyperion, the seventh in order of distance, and eighth in order of discovery, of Saturn's numerous family. The disclosure to Prof. Hall, August 16th, 1877, of Deimos and Phobos, the dwarf moons of Mars, was the most eminent performance of the Washington twenty-six-inch refractor, which for some years held the telescopic primacy of the world; and it was with a later champion instrument, the Lick thirty-six-inch, that Prof. Barnard descried, September 19th, 1892, the small body called, without rhyme or reason, the "fifth satellite of Jupiter." Among the eight principal planets, Mercury and Venus alone remain unattended; and this circumstance is, more than probably, connected with their peculiar mode of rotation. Each—as Schiaparelli announced in 1889-90—turns on its axis in the same time that it revolves round the sun, keeping, like our moon, the same face always towards the central body. This agreement was, doubtless, brought about by the grinding down of axial movement through solar tidal friction, the epochs of instability leading to the birth of satellites being, as a secondary effect, forestalled. The importance of tidal friction in cosmogony came to be recognized through Prof. Darwin's brilliant research into the origin of the moon. It was presented to the Royal Society in 1879. The predominance of the same influence over the development of stellar systems was ably shown by Dr. See, of Chicago, in 1892.

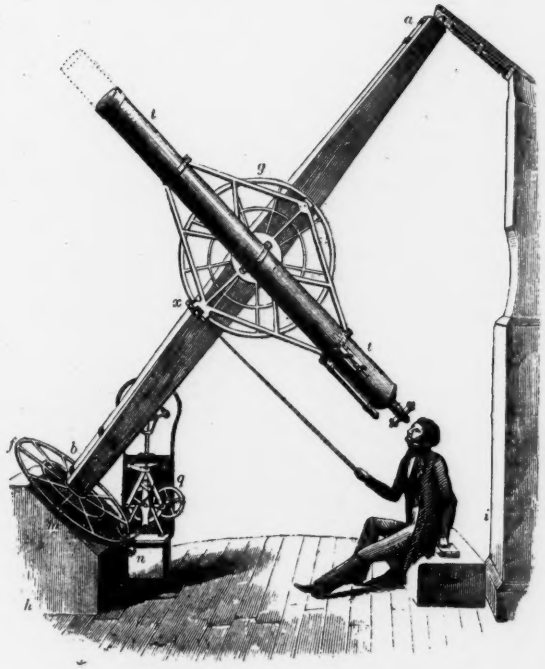
Bond's perception of Saturn's "crape ring" led to a revival of curiosity as to the mechanism of the whole set of appendages, and the problem was solved by Clerk Maxwell in 1857. Their formation out of separately-revolving small bodies, demonstrated by him on abstract grounds, was beautifully confirmed by Prof. Keeler's spectrographic experiments in 1895, showing that the radial velocities in the different parts of the system had precisely their theoretical values.

Ideas regarding the nature of the planets and their central luminary have been profoundly modified during the last sixty years. The four outer planets now rank as "semi-suns," plastic by virtue of their proper heat; while Schiaparelli's discovery of the canals of Mars, and their mysterious duplications, have tended greatly to impair the analogy, so apparent to Herschel, between that globe and the earth. In 1837, too, Herschel's theory of the sun reigned without a rival. It now seems as obsolete as that of Anaxagoras. The solar mode of rotation, by surface-drifts slackening towards the poles, discovered by Carrington from spot-movements, and reaffirmed from spectroscopic evidence by Dunér, cannot be that of a solid body; and all the observed phenomena point to the activity of vertical convection-currents on a prodigious scale, effecting the requisite exchanges of heated and cooled material between the interior and exterior, the expenditure in radiation being supplied by an income from gravitational shrinkage. Uncertainties of long standing and uncomfortable amount as to the temperature and distance of the sun, have lately been, to a great extent, abolished. The photosphere appears, from experiments made by Messrs. Wilson and Gray in 1894, to be much more than twice as hot as the electric arc, its temperature being about eight thousand degrees centigrade. And Dr. Gill's measures of the minor planet Sappho, in 1889, fix the "astronomical unit," or mean radius of the earth's orbit, as ninety-two million eight hundred thousand miles. This value is unlikely to be materially altered.

The comets of the reign have been in many ways remarkable. Those that appeared in southern latitudes in 1843, 1880, 1882, and 1887, followed each other nearly in the same path, and passed close to the sun with tremendous speed, demonstrating by their unretarded course the

inconceivable tenuity of the solar surroundings. Like other similarly related comets, they probably are fragments of a single disrupted mass. The intimate connection of comets and meteors was indicated by Schiaparelli in 1866 on the ground of orbital identities, and was illustrated by the reappearance of the vanished Biela under the guise of a star-drift. The electrical nature of cometary illumination has been confirmed by varied evidence. Bredichin's hypothesis of the three types of comets' tails has proved a useful aid to research; and the presence of hydro-carbon bands in their spectra, first recognized by Dr. Huggins in Winnecke's comet of 1868, has turned out to be all but unfailing. Finally, there is no longer reason to doubt that the undisturbed motion of these strange bodies is approximately parabolic, and that the periodicity of some among them has resulted from "capture" by the great planets.

Celestial sensations have not been wanting. The Victorian age has witnessed the outburst of no less than seven new stars. T Coronæ, the first spectroscopically examined, showed itself to Dr. Huggins, May 16th, 1866, as wrapt in a mantle of blazing hydrogen; and its condition was typical, though not inevitable. The changes in quality of the fading light of such objects are significant and curious. Thus, Nova Cygni in 1876, Nova Aurigæ in 1892, and Nova Normæ in 1893, displayed, to begin with, spectra of the chromospheric type, which gradually assumed nebular affinities.



A Form of Equatorial common in 1837.

All that is known about the distances of the stars has been learned since the Queen's accession. Near the close of 1839, Bessel announced a genuine parallax for 61 Cygni; two months later, Henderson communicated his detection of a larger one for α Centauri. This splendid southern binary has not, so far, been superseded as the sun's nearest neighbour; yet its light spends four years and four months in traversing the intervening twenty-five billions of miles. Sirius and Procyon are about twice as distant; two or three insignificant, swiftly moving objects are of intermediate remoteness. On the whole, about seventy stars are ticketed with nominal parallaxes, of which, perhaps, half may be depended upon as real. Those measured with the heliometer by Drs. Gill and Elkin are of high authority; but henceforward the photographic method introduced by the late Prof. Pritchard will doubtless be extensively employed.

The immense enlargement in the power and scope of astronomical research effected during the last few decades was strikingly illustrated by Sir George Airy's administration at Greenwich. His deliberate policy was to keep the Royal Observatory true to its ancient purposes, nor has it ever departed from them. Yet, born successor of Flamsteed though he was, his mind was open to conviction; and he created, within a stone's throw of the spot where Flamsteed had set up his iron sextant, a magnetic, a photographic, and a spectroscopic department. The sister establishment in the southern hemisphere, by the activity of which England's universal dominion over the seas is extended to the skies, is about to follow suit. In a year or two, through the generosity of Mr. McClean, a great astrophysical apparatus will be erected at the Cape, and Imperialism will triumph in the New Astronomy.

Prof. J. C. Adams.

THE POLAR BEARS AT THE "ZOO."

By F. E. Beddard, F.R.S.

THE Polar bear is a beast which—contrary to what might be supposed—does well at the Zoological Society's Gardens. During recent years there has been a continuous supply of the creature, and one individual lately nearly topped the record of longevity in the menagerie by surviving for no less a period than thirty-seven years. Instances of this kind—and many might be cited from the collection in the Regent's Park—show how independent in certain cases are animals upon their surroundings, and how futile were some of the earlier attempts to explain the geographical range of species by supposed necessities of climate and other inanimate surroundings. The Polar bears at the "Zoo" thrive in the absence of sea-water and of ice, as may indeed be seen at once from our engraving, which represents the active couple of bears now on view. To the ordinary visitor to the Zoological Gardens the Polar bear is chiefly attractive—at least in the case of the two young bears now there—on account of its frequently amiable activity—its playfulness of habit; also, perhaps, as are many other animals, as a *corpus vile* for experiments in the way of food. In an obliging way the two young occupants of the Polar bears' cage will play with a bun or a biscuit offered by some visitor who does not grasp the propensities of animals with large canine teeth. To the naturalist the Polar bear is interesting for other and different reasons. It is one of the animals which have an absolutely descriptive vernacular name. The Polar bear is one of the very few mammalian creatures which are strictly Polar in range.

Mr. Lydekker, indeed, in his excellent "Geographical Distribution of Mammals," only enumerates four others." Why the beast should have selected so desolate a country for its habitat is curious, seeing that it is a powerful creature, fully capable of holding its own in more favoured climates; its range can be hardly comparable to that of the Bronze Age man, driven to the uttermost corners of Europe by invading iron-smelting races. Yet it seems to be the fact that its range has been curtailed, for a skull referable to the existing *Ursus maritimus* has been found in the diluvium near Hamburg, thus proving incontestably a former extension to the southward, though it is, of course, highly possible that at the same time ice and snow were also more extended in the same direction. Many naturalists will put this down to the whiteness of its fur. At first sight this does not appear an obvious kind of correlation. Yet in a country where all is white a harmony of tint has its uses. Though the Polar bear is large and powerful, it is not overweighted with brain; a gigantic frame is not always accompanied by development of brain in due proportion. Why, then, as an old writer poetically put it, does the Polar bear "sway his rude sceptre over the icy mountains of Greenland and Spitzbergen"? It is possible—at any rate, it has often been asserted—that the whiteness of the Polar bear is an advantage, not, indeed, in escaping its foes—though they are limited to those of its own household—but in stealing quietly and unobserved upon its prey. It might be that in milder climes the bear was at a positive disadvantage in this respect, and that, in consequence, it gradually retired to the fastnesses of the extreme North. But a white skin has other uses than those in a cold climate. It helps to keep the body warm, in that it prevents the giving off of heat more than would a skin of any other colour. We can see, therefore, a fitness in the colour of the Polar bear. And yet this popular and apparently reasonable explanation of the bear's hide is not without its opponents. "It seems hardly right," wrote Sir Leopold M'Clintock in "The Voyage of the *Fox*," "to call Polar bears land animals." And those who have seen Mr. Swan's fine picture of the bears swimming in the Polar sea will remember how exceedingly conspicuous the painter has, doubtless with reason, made them to look amid their surroundings. Then, too, the bear often acquires, with advancing years, a brown colour, quite noticeable in the old bear at the "Zoo," of whose creditable longevity we have already made mention. So much so, indeed, that whale hunters from Scotland frequently speak of this dreaded beast by the flippant name of "Old Brownie." The brownness of our specimen at the "Zoo" was wrongly put down by some to the sooty atmosphere of this city. Again, according to the same authority who has just been quoted, the Polar bear seems to prefer hunting by night; and in darkness it might be any colour with equal advantage, or still any colour if moonlight and starlight threw strong shadows. It cannot, in fact, be assumed offhand that the whiteness of the bear's pellage has any definite relation to the ice and snow amongst which it lives. Like many of the inhabitants of the North—such as, for instance, the notorious lemming—the Polar bear is a great traveller; but, unlike that restless rodent, it does not deliberately voyage: its journeys are to a large extent involuntary, and are due to the breaking off of bits of ice upon which the bear happens to be. It is thus sometimes carried away even so far from its proper home as Iceland. Bears have been found floating on ice, so it is said, as much as two hundred miles from the nearest land. Olaus Magnus, the excellent Archbishop of Upsala, tells us of "Ursi albi maximi et fortissimi" found in Iceland; these have been carried thither in some such way, for the Polar bear cannot be considered to be a native of that island. Skins of these bears were frequently offered by hunters, the Archbishop further remarks, to various churches, "in order that the priest when celebrating mass at a time of terrible cold may not suffer from his feet." The Polar bear, in fact, as his habits show, is an amphibious creature, well on the way to become purely aquatic in mode of life. It offers a hint, in fact, of how the sea lion may have sprung from a terrestrial ancestor. The feet of the Polar bear are already very large; make them larger and shorten the leg in a corresponding fashion, and the flipper of the sea lion is nearly arrived at. Zoologists think that of all land carnivora the marine walruses, seals, and sea lions are most nearly akin to the bears; so that the expression "sea *lion*" is so far misleading as to the affinities of the animal. But it is after all rather in habit and ways of feeding that the *Ursus maritimus* has gone somewhat sealwards. Its structure, though sufficiently divergent from that of other bears to justify, according to some, its separation as a distinct genus, *Thalass arctos*, is not really greatly modified. It is, indeed, one of many instances which show that change of function frequently precedes change of structure. With the equipment of the most ordinary forest-living and honey-feeding bear, the Polar bear pursues a totally different kind of game, proving a match for the active seal and for still more active fish. This bear, feasting, as it does, upon seals, or, on occasions, upon the decaying carcass of a whale, has yet got a reputation for ferocity which seems to be a theory founded upon its size, and to be largely apochryphal. The friendly manner of the two young beasts now at the "Zoo" will, to some extent, dispel this view, which most travellers who have had experience of the animal in its native places disbelieve. It has, however, to judge from what we are told by Mr. R. Brown, a "temper." He relates that, having unsuccessfully stalked a seal, a large bear exhibited signs of considerable annoyance. "The rage of the animal was boundless; it roared hideously, tossing the snow in the air, and trotted off in a most indignant state of mind!" With regard to human beings the bear is comparatively mild—if let alone. Sir Leopold M'Clintock tells of "a native of Upernavik" who one day "was out visiting his seal-nets. He found a seal entangled, and, whilst kneeling down over it upon the ice to get it clear, he received a slap on the back—from his companion, as he supposed; but a second and heavier blow made him look smartly round. He was horror-stricken to see a peculiarly grim old bear instead of his comrade! Without deigning further notice of the man, Bruin tore the seal out of the net and commenced his supper. He was not interrupted; nor did the man wait to see the meal finished."

More unpleasant was the experience of Mr. Brown and his companions. "In 1861," writes Mr. Brown, "I saw upwards of twenty all busily devouring the huge inflated carcass of a *Balæna mysticetus* in Pond's Bay, on the western shore of Davis Strait. We were foolish enough to fire a few shots among them, when the bears sprang furiously from the carcass and made for our boat. One succeeded in getting its paw on to the gunwale, and it was only by the vigorous application of an axe that we succeeded in relieving ourselves of so unwelcome an addition to our crew." The fact seems to be that the Polar bear, like many other wild and carnivorous beasts, takes no particular notice of man unless unduly provoked to do so by hunger or too marked an interference. When it does make up its mind for revenge or food, it proceeds in a fashion that marks it out from other bears; instead of *hugging* its victims as they do, it *bites*.

POLAR BEARS AT PLAY. Zoological Society's Gardens, Regent's Park.

From a Photograph by HARRY F. WITHERBY.

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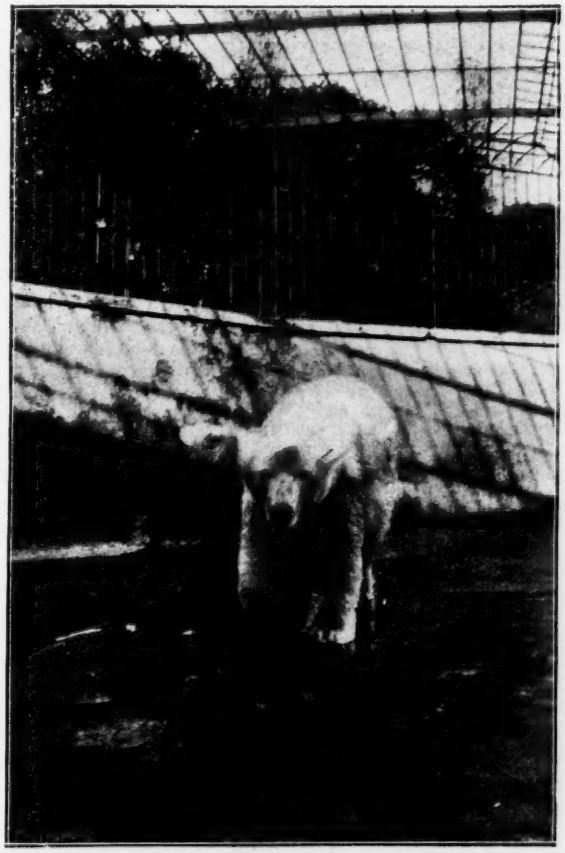
So much, then, for the manners and customs of the Northern Bruin. We have been hitherto considering the bear from his own point of view. The older naturalists, and many of the laity, now dwell rather upon the uses of creatures to man. They take what was termed by Prof. Haeckel an anthropocentric view of the universe. From this point of view the bear does undoubtedly come in. We have already referred to the pious offerings of the Northern sportsmen; but the bear provides not only dress, but meat and oil. The intrepid Willem Barents, one of the pioneers of Arctic exploration, did not realize that the bear was excellent eating; subsequent travellers have, and, oddly enough, some of them describe the flesh as tasting



Polar Bear charging. (Zoological Gardens.)

like mutton: oddly, because all strange meats, for some reason or other, are frequently compared to veal.

We have now considered the Polar bear from the point of view of the British public, the naturalist, and the gourmet.

[The last sentence in Mr. Beddard's article reminds me that he has not treated of the Polar bear from a photographer's point of view, and a few remarks on the subject may not be out of place here.

As Mr. Beddard says, the two Polar bears now in the "Zoo" are very fond of playing together, and they may be seen biting at each other, wrestling, and rolling over for hours at a time; but I found it exceedingly difficult to photograph them in the act of playing. Immediately I approached the bars they would leave off their game—no doubt in the hopes of playing with me! The only thing to do was to wait quietly for a chance of a snap-shot, which, after several hours, I eventually obtained. This has been enlarged, and is reproduced in the accompanying plate. The smaller illustration is of one of the bears charging. Both Dr. Nansen and Mr. Jackson have, I believe, taken photographs, at about fifteen yards, of bears in their wild state in the act of charging, and have then laid down the camera, taken up the rifle, and shot the bear. With these captive bears I don't think this would be possible, for they charge straight up to the camera at a tremendous pace, without any check.

When taking this photograph, a friend enticed the beasts up to the further end of the inclosure, and while he was playing with them with a stick, I crept up to the bars with my camera ready. No sooner had I put the camera through the bars than one bear charged at full speed. I allowed him to come within twelve feet, and then snapped the shutter, and immediately drew my camera away. On several occasions I was only just in time, for the beast grazed me with his paw. Personally, I should not care to photograph one of these bears charging, without the protection of the bars.—Harry F. Witherby.]

A PANTHEON OF SCIENCE.

By John Mills, F.R.A.S.

THE opening of the Davy-Faraday Laboratory in December last, with all its resources for prosecuting original research in chemistry and chemical physics, marks, in its way, an epoch in the history of applied science in this country. Additional interest attaches to the event because it practically forms the centenary of the Royal Institution of Great Britain, which, a hundred years ago, was first conceived by Benjamin Thomson, a Royalist American in the service of the Elector Palatine of Bavaria, by whom he was created a Count of the Holy Roman Empire. "History repeats itself," is a saying which we often hear; and it is worthy of remark, in this connexion, that a dwelling-house, adapted to the exigencies of the case, served as a beginning for the requirements of the projectors of the Royal Institution, just as the Davy-Faraday Laboratory of to-day has been metamorphosed from a gentleman's private residence into a series of small laboratories for the accommodation of persons desirous of investigating scientific problems. Some idea of the immense progress which has been made in the several branches of science in the interval which separates the epochs marked by the beneficent acts of Count Rumford and Dr. Ludwig Mond, may be gathered by the perusal of the series of articles—"The Science of the Queen's Reign"—now appearing in this magazine.

It has been said that the history of the Royal Institution is the history of science in England; should anyone doubt the truth of this assertion, let him but read the records of the Institution's aims, aspirations, and actions, and we venture to think that the most sceptical will discover therein the initial points of many great schemes for increasing the sum of human happiness—some of which have been accomplished, and others still exist in the mind only. The Institution was launched in March, 1799, the first meeting of the managers being held at the house of Sir Joseph Banks (chairman), in Soho Square, Count Rumford as secretary, and Mr. Thomas Bernard as treasurer. Rumford had previously circularised those persons likely to be of use in supporting the venture both by personal influence and with pecuniary help, and a

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number of fifty-guinea subscribers, called proprietors, were thus obtained. A house in Albemarle Street was bought, and its apartments were transformed into lecture rooms, model rooms, library, offices, etc. Its objects were for the purpose of diffusing knowledge, and facilitating the general and speedy introduction of new and useful mechanical inventions and improvements; and also the teaching, by regular courses of philosophical lectures and experiments, the application of the new discoveries in science to the improvement of arts and manufactures, and in facilitating the means of procuring the comforts and conveniences of life.

Just now, when the Government is about to be asked to provide a National Patent Museum from the immense funds netted from fees paid by applicants for letters patent at the Patent Office, it may be interesting to know that the same idea was conceived, and, to some extent, carried into effect, privately, a century ago at the Royal Institution. It was part of Rumford's plan to collect all manner of appliances together, including "that curious and useful machine, the steam engine," so that anyone desirous of making headway in the arts and industries might have opportunities of studying the latest inventions gathered, not only from all parts of England, but also from foreign countries. Since then, something has been done at South Kensington in the way of practically illustrating the progress of invention, but it is far from what it ought to be, and inconveniently situated for those immediately concerned.

STATUE OF MICHAEL FARADAY: ENTRANCE HALL, ROYAL INSTITUTION.

Ever since the time (1842) when Liebig came over from Germany as a sort of scientific missionary, and lectured in London and the chief provincial towns on the applications of chemistry to agriculture, etc., we have been accustomed to the theme of technical education, the blessings of which have been dinned into our ears by men of all denominations, ranks, and professions; and only within the last few years have the concessions prayed for been conceded. But although Liebig, backed up by Playfair and others, gave a great impetus to the movement which has terminated so gloriously, it is not to him or his contemporaries that we must look for the source of the current. Referring again to the schemes of the projectors of the Royal Institution, we read: "It is intended to educate a number of mechanics sent by the proprietors of the Institution. At first all will learn the same elementary principles, but afterwards they will branch off according to their several trades—bricklayers, joiners, tinmen, iron-plate workers—in conformity with their needs." In a large room, on the ground floor, they built up, for practice, chimneys and fireplaces of all kinds in a slight manner, pulled them down again, and built up others. Models of various culinary vessels were made from ideas of Count Rumford, and were put in the model room for the inspection of the public. Dinners were cooked in the Institution, and people were invited to witness the operations involved and to test the quality of the products. It requires no great effort of the imagination to see in these words the perfect images of the modern technical college and school of cookery. Indeed, the ideas advanced by these pioneers of applied science are as clearly enunciated and as accurately formulated as those put forward by the leading men of our own day; and the words of Rumford, uttered in the last century, are as pregnant with thought and as applicable now to the future as if they had been spoken at the opening of the Davy-Faraday Laboratory: "In estimating the probable usefulness of this Institution, we must not forget the public advantages that will be derived from the general diffusion of experimental investigation and improvement among the ranks of society. When the rich shall take pleasure in contemplating and encouraging such mechanical improvements as are really useful, good taste—with its inseparable companion, good morals—will revive, rational economy will become fashionable, industry and ingenuity will be honoured and rewarded, and the pursuits of all the various classes of society will then tend to promote the public prosperity."

Rumford, from the outset, threw himself with great zeal

and ardour into the work of organising and starting the institution. He was requested by the managers to live in the house, to superintend the servants, to preserve order and decorum, and to control the expenses of housekeeping. Not the least strange fact in the history of this original man, however, is that during his life he received no thanks for all that he did for the Royal Institution. At the present time he is scarcely known as the founder of the place where very many of the greatest scientific discoveries of this century have been made; and as to technical education, who ever heard his name in association with the movement?

In 1799 Dr. Thomas Garnett, known to chemists for his researches into the composition of the Harrogate mineral waters, was invited by Rumford to become lecturer and scientific secretary, and, "in the Northern accent . . . which rendered his voice somewhat inharmonious to a London audience," began his lectures in March, 1800; but differences having arisen between him and Rumford, he was called upon to retire in the following year. The following extract is from the minute-book of the Royal Institution of a resolution adopted at a meeting of the managers on February 16th, 1801: "Resolved—That Mr. Humphry Davy be engaged in the service of the Royal Institution, in the capacities of Assistant Lecturer in Chemistry, Director of the Laboratory, and Assistant Editor of the Journals of the Institution; and that he be allowed to occupy a room in the house, and be furnished with coals and candles; and that he be paid a salary of one hundred guineas per annum." Davy's discovery of nitrous oxide—the pleasure-producing air, as he himself calls it in one of his letters—had, in the previous year, made him somewhat famous, his experiments having been repeated, with the greatest success, by the professors of the Edinburgh University; and through some friend or friends he was brought to the notice of Count Rumford. In a letter to Dr. Hope, Davy says: "I believe it is in a great measure owing to your kind mention of me to Count Rumford that I occupy my present situation in the Royal Institution. I ought to be thankful to you . . . . as I am enabled to pursue my favourite study, and at the same time to be of some little utility to society." It is said that the first impression produced by Davy on Count Rumford, who appears to have been a sort of autocrat in the Institution, was highly unfavourable; but his first lecture entirely removed every prejudice. "Let him command any arrangement which the Institution can afford," said the Count. By June 1st the managers had passed the following resolution: "Resolved—That Humphry Davy be appointed, and in future denominated, Lecturer in Chemistry at the Royal Institution, instead of continuing to occupy the place of Assistant Lecturer, which he has hitherto filled."

A month later we find him ordered to give a course of lectures on the chemical principles of the art of tanning, although he had probably never had more than an outside view of a tannery; but any deficiencies in this respect were in part compensated by leave of absence from the Institution during the months of July, August, and September, for the purpose of making himself more particularly acquainted with the practical part of the business of tanning. Davy, however, could command a felicity of expression and a dignity of treatment which invested the homeliest themes with interest. Men of the first rank and talent—the literary and the scientific, the practical and the theoretical, blue-stockings and women of fashion, the old and the young, all crowded—eagerly crowded—the lecture-room. The vicissitudes through which the Institution, in its early days, struggled were more than counteracted by Davy's popularity, without which it could not have survived. The small, spare youth (he was only twenty-two years of age), with his earnestness, his eloquence, his speaking eyes—"eyes which," as one of his fair auditors was heard to remark, "were made for something besides poring over crucibles"—held his hearers spellbound as he declaimed in periods like the following:—

"In reasoning concerning the future hopes of the human species, we may look forward with confidence to a state of society in which the different orders and classes of men will contribute more effectually to the support of each other than they have hitherto done. This state, indeed, seems to be approaching fast; for, in consequence of the multiplication of the means of instruction, the man of science and the manufacturer are daily becoming more assimilated to each other. . . . We do not look to distant ages, or amuse ourselves with brilliant though delusive dreams concerning the infinite improvability of man, the annihilation of labour, disease, and even death; but we reason by analogy from simple facts; we consider only a state of human progression arising out of its present condition; we look for a time that we may reasonably expect, *for a bright day of which we already behold the dawn.*"

It was at the end of the year 1812, under such glowing phrases as these, that Faraday was infected with an irresistible desire to become a votary of science. Having carefully written out notes of one of Davy's lectures, he sent the fair copy, and at the same time took the bold and simple step of writing to the great man expressing a hope that, if an opportunity came in his way, he would do something to aid him in his aspirations. In a letter to Dr. Paris, Faraday says: "My desire to escape from trade, which I thought vicious, and to enter into the service of science, which I imagined made its pursuers amiable and liberal, induced me to do this. Early in 1813 he requested to see me, and told me of the situation of assistant in the laboratory of the Royal Institution, then just vacant . . . . He smiled at my notion of the superior moral feelings of philosophic men, and said he would leave me to the experience of a few years to set me right on that matter." In the minutes of the meeting of managers on March 1st, 1813, we read: "Resolved—That Michael Faraday be engaged to fill the situation lately occupied by Mr. Payne on the same terms."

Such is the story, in brief, of the capture of these two notable men—Davy and Faraday—by the promoters of the Royal Institution: a classic building, with its fluted columns topped by Corinthian capitals, hid away from the gaze of the rabble in Albemarle Street like some hidden secret of science itself.

'TWIXT LAND AND SEA.

By Harry F. Witherby.

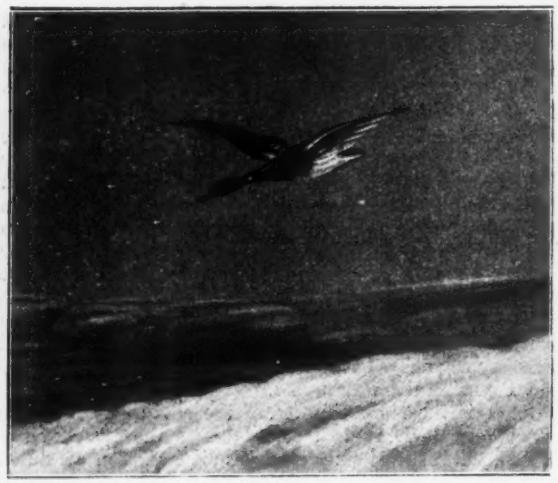
"And now it's a whaup, and now it's a scaup,
When you shoot along the shore."

THE moon is paling before the coming dawn as we reach the river-bank on a cold winter morning. We have risen early, as should all keen shore-shooters, to be down at the river in time for the ducks as they take their morning flight. So we crouch and wait behind the high "sea-bank." Before us, over the flat land, and along the low hedges, shadowy forms are flitting, and the air is quivering with that indescribable twittering which heralds the break of day. Then we hear "peewit, peewit," and we see dimly the lapwing whirling hither and thither. But what is that? We are nearly dreaming, and start, and grip the gun. "Swit, swit, swit," first like the twitter of a small bird, then nearer and

nearer, until the rhythmic "swish, swish, swish," of wings is plain. We look up, and soon the form of a duck appears, but, alas! too high up—out of shot. The flight has begun. Ducks, singly and in flocks, pass over continually, but all out of shot, for the morning is calm and clear, and birds generally fly high in such weather.

And now the sun is above the horizon, and the flight is over, so we get up and stretch our cramped limbs, and look towards the river. The tide is far out, and away over three dreary, desolate miles of wet and shining mudflats the water can just be distinguished, shimmering in the light of the rising sun; and far beyond, the further shore looms mistily in the early light. But there is plenty to delight the eye of the naturalist even in this great waste.

Little flocks of dunlin and ring plover, or oxbirds, as they are called, collectively, are feeding not far off; a great "bunch" of knot and plover are wheeling and whirling over the mud, and the cry of "curlew, curlew," comes from the distant tide. Gulls are soaring overhead, and there, on a little colony of mussels, working hard to obtain their food, which will soon be covered by the tide, is a conspicuous flock of black and white oyster-catchers, or sea-pies, as shorefolk call them; and thus that which seemed at first glance a desolate expanse of mud is in reality a vast feeding ground for birds.



Wild Duck flying from the Land.

Reproduced from a painting by "A Son of the Marshes."

The birds are there in plenty, but how can we get at them? We know by experience that one might tramp up to the knees in that mud for a day without getting near a bird. The only thing to do is to wait for the tide to rise and drive in the birds. Meanwhile we employ our time—most profitably, too—in watching.

A great flock of knot and plover first absorb our attention. It is a curious fact that many shore birds which form into flocks in the winter appear to take exercise, and, one might perhaps say, find amusement, in performing the most wonderful evolutions on the wing. As we watch this flock it suddenly splits into several companies, which separate and settle down upon the mud, and we begin to think that the play is over. But no! Without warning, the biggest flock ascends with a noise like the distant roar of the waves as they break on the sands. This seems a signal, for up get the other flocks and join the first—all save one, which flies up higher and over the main "bunch," then with a headlong rush it dashes down as one, into the midst of the black mass below. We start, for surely some birds have collided and will fall dead upon the mud; but before we can rise, the flocks have joined, and the whole fly on, like a monstrous swarm of bees.

This is but the beginning of the manœuvres. The birds have their sides to us and the whole bunch looks black, when, in a moment, it becomes a glistening white, then black again. The whole six thousand or more have turned together and shown their silvery undersides. Now they are tailing out into a line half a mile long with a bunch at the head, taking the form of a gigantic snake. The line is, perhaps, thirty deep in the thinnest part, yet it is waving up and down and from side to side like a pennant in a gusty gale. Not a bird is too fast or too slow. They might be tied together, so even is the line. Tired of this, they form a V, then a square, then a circle; and so, with endless changes and surprising tactics, they fascinate us for an hour or more, and finally settle down by the tide to feed and rest.

To those who have not watched these wondrous evolutions all this may read as a fable, and to those who have, comes the question, What guides and directs these sudden but perfectly unanimous movements? Does one bird act as leader? and since that in a large flock not half the individuals would be able to see the leader, is the motion transmitted from one to another? We think not. Birds, no doubt, have vastly quicker perception, and can act upon this sense much more rapidly, than ourselves; but could a transmitted motion, however quickly it was performed, account for six thousand birds turning over on their sides at the same moment? Currents of air may have some effect, but the problem has yet to be solved—and it is an engrossing one.

But let us return to the birds on the mudflats, or slubs, as they are called in some parts. The tide is coming in now, and the birds are moving in too, so we hide up in little creeks about a hundred yards apart from each other. This is wet and dirty work, sitting on one's gamebag in the mud and crouching low, with slush over the ankles; but it is the sort of position that comes naturally to the shore-shooter, and is not thought anything of.

The curlew are the first birds to move. Rushing over our heads to the land, they give us some very difficult chances, and at last we drop one in the mud. We wade through the slush and pick him up. What a lovely bird, with his long downward-curved bill, his white breast streaked with brown, and his brown back streaked with black!

The curlew, or whaup, is indeed a prize, for of all 'long-shore birds he is the wariest and most difficult to shoot. You cannot stalk him, and the only successful way is to hide and wait for him to fly over you; and many a time has he got the best of it when he has been right overhead and I felt sure of him. As soon as you move the gun he sees you; however fast he is flying he will dash off at right angles and be out of shot before your gun is on him, for you cannot turn quickly when your legs are held fast by the mud.

The knot and plover have now risen and are flying up and down the stream. A small flock pass within shot, and we bag a couple of knot and a grey plover. The knot at this time of year are dark grey with whitish breasts. In summer one would hardly recognize them. Their breasts are a lovely chestnut, their heads and necks are reddish brown, and their backs blackish. There is a mystery about these birds. In autumn and winter they frequent our shores and tidal rivers, in tens of thousands; but their breeding haunts no man knows! It is true that the young

birds in down have been found once or twice in high latitudes, but the eggs have never yet been authenticated.

The grey plover, much like the golden plover, but easily distinguished by the black axillaries under the wing, and by the hind toe (the golden plover has none), is a lovely enough bird in winter: but he, too, is far more beautiful in summer.

Just as we have settled down again, after picking up our birds, a flock of fifty widgeon fly in from seawards, and splash into the water about two hundred yards from us. Now we are all excitement. It is not every day that a shore-shooter has a chance at widgeon, so we sit as still as stones as they gradually drift in with the tide. At last they are within a hundred yards of the shore, and we can see every feather with our glasses, and notice that, besides the widgeon, there are several scaup-duck in the flock. Some are diving and some are preening their feathers, and now and again an old male widgeon sounds his melodious, long-drawn "whee-ou"—some people call it harsh and shrill—but all seem unconscious of our presence. So intent have I been in watching that, until the cold strikes me, I have not noticed that the tide has filled the creek and crept up my leg! They are still drifting in, and another twenty yards nearer we shall fire; but, alas! they have, perhaps, seen me draw my leg out of the water, for slowly and leisurely they paddle out again. Our hopes are shattered, so we console ourselves with luncheon, and discuss the ways of birds over a pipe. As the tide goes down the dunlin fly from off the land, and we get a few, which are wanted for a special purpose. Nothing further rewards our labours for that day until the sun is setting, and we wait for the evening flight.

During the day the wind has been rising, and now a fine snow is falling. The ducks coming in from the river fly low and heavily against the wind, which is off the land. Many a cartridge is fired in vain before we hear the welcome sound of two thuds upon the grass behind us, and we pick up a fine pair of mallard. Flighting in the dusk is by no means certain shooting. If there are bright clouds above, the birds can be easily seen, but it is exceedingly difficult to judge of height and pace—knowledge which is indispensable for accurate shooting.

We trudge home that night with high hopes for the morrow, for this snow will surely drive the birds off the land to feed by the open water.

SNIPE FEEDING IN A CREEK ON THE SNOW-COVERED SALTINGS.

Reproduced from a painting by "A Son of the Marshes."

We spend the next day up a small offshoot of the main river, where salt marshes border the stream. These saltings are familiar objects on the east coast of England. They are slightly raised above the water, and only the highest tides completely cover them. They are overgrown with rank grass and weeds, and are intersected with small muddy creeks, up which the tide runs.

Just as we reach the saltings and are walking carelessly along, continually jumping over the small creeks, a pair of lovely shieldduck rise within eighty yards of us, showing off their striking plumage of black and white and chestnut. Had we been more careful, both those ducks might have been brought to bag.

Then up gets a snipe from a patch of mud uncovered

from the snow, and down he comes, cut short in that puzzling zig-zag flight. "Lucky shot," says my companion, to which I vouchsafe no reply.

A long way off we can see a flight of hooded crows making for the mud, so we run to the bank and crouch under it. In three or four minutes the first crow is right over our heads; he sees the danger, and immediately his lazy flap becomes a quick rush; but too late—the shot brings him down, and there he lies black and grey in the green grass. However, he has saved his brethren, for they hear the gun and see his fall, and turning back take a big curve to the right.

If any birds are cruel, certainly it is the hooded and the carrion crows. We always make a point of killing them whenever possible. They destroy every egg and small bird they can, and worry every weak or sickly thing they find, as "A Son of the Marshes" has pathetically illustrated in one of the accompanying engravings. The hooded crow is abundant in Ireland and Scotland during the summer, but not in England. In the autumn, however, great flocks come over from Scandinavia and the Continent, and they thus become very numerous on our east coast in winter. They are exceedingly difficult birds to approach, being extremely wary and watchful.

For instance, at high tide these birds delight to feed along the edge of the water just under the sea-bank. We have often tried to stalk them by creeping along the other side of the bank, but the crows are very seldom outwitted by this device. Every minute or two one of them flies up a short distance and takes a look round, and immediately sees the man on the other side of the bank, gives the alarm, and away they all fly, to settle a couple of hundred yards or so further off. One soon gives up that way of trying to outwit a hooded crow.

My last piece of work this day, which was altogether an unlucky one, was a long stalk for a grey plover. We had marked him down on the mud within easy shot of the edge of the saltings. To get to the edge without his seeing me was the difficulty. I start by walking with body bent, in the wet clinging mud along the bottom of a winding creek, then comes a snake-like crawl through the snow across to another creek; another crouch and another crawl bring me to the edge of a creek, which winds right up to the very place I wish to reach. I begin to count the grey plover my own, when turning a corner I come in full view of two redshanks feeding by a pool. Now I know my careful, trying stalk is all in vain. The shankers see me and up they get, yelping as only the "cussed yelpers," as fenmen call them, can. One pays the penalty, and his skin is now in my cabinet, but that grey plover never will be mine.

The Wounded Hare.

"No more the thickening brakes and verdant plains
To thee shall home, or food, or pastime yield."

Reproduced from a painting by "A Son of the Marshes."

The engravings illustrating this article are from original oil paintings by "A Son of the Marshes," and have been very kindly lent by Alfred Beaumont, Esq., of Blackheath, Kent.

Science Notes.

During the last fifty years much work has been done by marine naturalists all round the British coasts, with a view to determining the distribution of those animals which live on the floor of the sea. It has been fully

recognized that the localities frequented by many marine species are very definite and extremely limited in extent, and that both the nature of the sea-bottom and the creatures which live there exhibit as much variety as we are accustomed to find on land. The Marine Biological Association, with the assistance of a grant made for the purpose by the Royal Society, has recently been engaged in an attempt to place our knowledge of this subject upon a sounder basis by investigating in detail some of the grounds in the neighbourhood of Plymouth, including important fishing grounds, with reference to the nature of the sea-bottom at each locality, and the whole assemblage of animals found there. Detailed charts are being prepared to exhibit the variations which take place from point to point. No attempt has previously been made to study fishing grounds with such thoroughness, having regard not only to the fishes, but the whole collection of animal life which forms the basis of the food upon which the fishes exist. The investigation, which has involved a large amount of dredging and trawling, as well as the identification of the numerous species captured, has been carried out by Mr. E. J. Allen, the Director of the Plymouth Laboratory.

From time to time, during the past few years, reports of the carrying of diseases by oysters have been published; but people have become so used to being scared that they mostly regard this indictment of the oyster as another bacteriological bogie. But the truth will come out, especially when the medical officer of the Local Government Board entices it; and we are afraid that the revelations recently made as to the condition of most of the places where oysters are cultivated and stored in England and Wales, will not add to the pleasure with which the luscious mollusc is consumed. Very few of the fattening beds, or of the ponds where oysters are stored pending their despatch to market, were found free from chance of sewage pollution. Southend, Cleethorpes, and the Medina in the Isle of Wight, are singled out for special condemnation. The oyster layings in the Penryn River, Cornwall, in Brightlingsea Creek, Essex, in the South Channel, off Southwick, near Shoreham, and to a minor degree those in the Menai Straits, also come under suspicion. Particularly offensive and dangerous storing places were found at Southend, Grimsby, Poole, Warsash, and Emsworth, near Havant. With so much depressing evidence, it is pleasant to read that the beds and the methods of storage on the Crouch, Roach, and Blackwater (with one exception), Helford River in Cornwall, and at Newtown Estuary in the Isle of Wight, leave little to be desired. If something is not done to bring other beds and storing grounds to the same sanitary condition, oyster breeders will certainly see the decline of their industry, especially as there is positive evidence that oysters are capable of transmitting the infections of such serious maladies as typhoid fever and cholera.

Notices of Books.

New Ground in Norway. By E. J. Goodman. (Newnes.) 10s. 6d. This account of a trip through the districts of Telemarken and Saetersdalen, in Southern Norway, forms an interesting book for reading as well as an excellent guide to the districts referred to. Mr. Goodman has considerable powers of description, both of scenery and of incident, but we think that in many instances too much detail has been given, which makes the book a little wearisome in places. Telemarken we know from personal experience to be a grand, but little visited, district, and Mr. Goodman's praise is none too high, either of the country or the inhabitants. The author dispels the bad reputation which has hitherto been given to Saetersdalen, and his vivid description of its beauties will, no doubt, cause many people to visit this fine district. The book is illustrated with fifty-six photographs by Mr. Paul Lange, who accompanied the author. These are of much excellence, both in composition and execution, and many of them form very beautiful pictures.

Euclid's Elements of Geometry. By H. M. Taylor, M.A. (Cambridge University Press.) 5s. It is marvellous to think that Euclid's elements of geometry, which the boys in our schools labour over to-day, were taught by the author at Alexandria three centuries before the commencement of our era. Numerous editions of the elements have been published, but few are more than reprints of previous ones. In this edition, however, originality is prominent. Some of the definitions are omitted, several are added, and a few are altered. The postulates and axioms familiar to those who have used such an edition of Euclid's elements as Todhunter's have been considerably modified. The result is that, instead of the twelve axioms and three postulates, Mr. Taylor gives seven axioms and nine postulates. The method of superposition is freely used in the propositions; and the word "respectively" is employed instead of "each to each." Impossible figures used in *reductio ad absurdum* proofs have been avoided; and the classification of the propositions into theorems and problems has not been followed. There are many other differences between Mr. Taylor's text and the text of most modern editions, but the majority of them will meet with approval. Not more than once in a generation is a geometrical work of such striking originality published.

Water Supply, considered principally from a Sanitary Standpoint. By Prof. Wm. P. Mason. (New York: Wiley. London: Chapman & Hall.) Illustrated. 21s. net. In the United States the subject of water supply seems to have been much more a ground for burning controversy than it has been in England. A country like ours, long denuded of primeval forests, where swamps have been drained and rivers are reduced within ordinary limits, has rarely such difficulties to contend with as are occasioned by heat and luxuriant vegetation, alternating with thicknesses of ice that almost baffle the engineers of the States. The work before us, dealing ably with local problems, has a very great American interest. On the subject of peaty waters, the author concludes that although in many instances they may be drunk without injury by those habituated, diarrhœa, and especially malaria, have, in a large number of cases, been conclusively traced to their use, but that these evils are obviated by efficient filtration.

A number of striking examples are quoted in which the Continental custom of washing linen in the public watercourses has led to violent outbreaks of cholera. Two epidemics of typhoid are described, one on the upper Hudson and one on the Susquehanna, both clearly traced to the sewage-polluted water of those rivers. A plan of the Chicago sewage outfalls and water intakes, with the distribution of typhoid in the different wards, enforces the same lesson. The Massachusetts statistics give the typhoid death rate, before the introduction of public supply, as 7·94 per 10,000; after its introduction as 3·83.

On page 192, in speaking of the gases evolved in putrefaction, an extraordinary statement is given on the authority of Dr. Leeds, that the polluted stream at Philadelphia having become frozen, "the flame produced by igniting the gas issuing from a penknife-puncture of the white hollows in the ice was usually six inches high, but was once fully a yard high." An account is given of the foul sources from which ice is commonly collected, and it is held that safety lies only in artificial ice prepared from

distilled water. In the chemical section the author voices the general opinion in pronouncing Frankland's combustion method to be difficult, liable to numerous errors, "and the results not indispensable for forming a correct opinion on the sanitary value of the water."

The illustrations, type, and general mounting are excellent, as would be expected from the high price; but the work itself is fragmentary, and would be improved by the omission, in a subsequent edition, of such irrelevant matter as the long description of the Festival of Juggernaut, etc., on page 48, and by a better digestion of the statistics.

The Land of the Monuments. By Joseph Pollard. (Hodder & Stoughton.) 7s. 6d. The writer who really loves his subject can hardly fail to interest his sympathetic readers, and the author of this book certainly has his heart in "the land of the monuments." Such as relish a story of travel told in a chatty way will appreciate the volume, even though there are not in it any very striking features. It is a matter for regret that photographs were not used in certain cases instead of a brush unable to render the majesty of Egypt's temples.

Results of Rain, River, and Evaporation Observations made in New South Wales during 1894. By H. C. Russell, B.A., C.M.G., F.R.S. In 1870 there were five stations reporting rain; in 1893 there were one thousand two hundred and eighty-seven; in 1894, one thousand three hundred and twenty-nine. These statistics will show how successfully Mr. Russell has worked and organized the extensive observation of the meteorology in New South Wales.

Though much of the matter contained in this volume is tabular, and therefore appeals only to an earnest student of meteorology, the introduction is devoted to the discussion of the statistics, and the knowledge that may be thereby attained of local rainfall and drought, and of evaporation from lake or river, sandy soil or grassy run or gauge.

The important factors in rainfall are the pressure of certain winds and the altitude of the station, the latter being especially effective if the ground rises rapidly to it. Wind also plays an important part in the amount of moisture evaporated, being of much greater account in a wide expanse of water like Lake George than on the small surface of a gauge. The effect of the humidity of the season must be also taken account of.

The most distinguishing features of the volume are the charts of temperature and rainfall. The first is a map of New South Wales, showing in black figures the average temperature for each month in the year in each square degree. A reticule of twelve squares covers each degree, corresponding to the months of the year. The second map gives the mean shade temperature for the four seasons, the mean shade temperature for the year, and the highest and lowest shade temperature recorded in each square degree. The third gives the number of inches of rainfall at each observing station.

The Indian Calendar. By Robert Sewell and Sankara Bâlkrishna Dîksit. With Tables of Eclipses visible in India by Dr. Robert Schram. (Swan Sonnenschein.) 31s. 6d. This is a work which very few besides its authors could criticize. The object of its compilation was a practical one. Documents bearing dates prior to those given in any existing almanack are produced before Indian courts of justice as evidence of title; and since forgeries, many of them of great antiquity, abound, it is necessary to have at hand means for testing the authenticity of such documents. Under these circumstances, Mr. Sewell was instructed by the Government of Madras to undertake the preparation of this great work, and in conjunction with Pandit Sankara Bâlkrishna Dîksit and Mr. T. Laksh Miah Naidu he has drawn up a set of tables for the following purposes amongst others: the conversion of any Indian date—luni-solar (*tithi*) or solar—into the corresponding date A.D. and *vice versâ*, from A.D. 300 to 1900, and finding the week-day of any such date; finding the *karana*, *nakshatra*, and *yoga* for any moment of an Indian or European date and thereby verifying any given Indian date; turning a Hindu solar date into a luni-solar date and *vice versâ*; conversion of a Muhammadan Hijra date into the corresponding A.D. date and *vice versâ*. The immense importance of such a work for judicial purposes in India is at once apparent. But besides this purely practical use, the book will be of great value to those interested in the history and antiquities of India, and to us even in England the work has a high astronomical interest. Eclipses have a special importance in the Indian scheme, as, being reckoned especially propitious days, important transactions were often negotiated upon such occasions or were dated from them. A very valuable feature of the work, therefore, is the appendix contributed by Dr. Schram, containing tables of all the solar eclipses in India for the thirteen hundred years included in the scope of the book. It is a work involving enormous labour, and has been carried out with the most sedulous care. And a most difficult subject has been treated with the greatest clearness and attractiveness of which the case admitted.

Navigation and Nautical Astronomy. By F. C. Stebbing, M.A. (Macmillan.) 8s. 6d. Necessarily the value of a new treatise on navigation and nautical astronomy must chiefly consist in the arrangement, style, and scope of the work, since the subject itself has been of such great importance to England as a nation that little has been left to be discovered in it. Briefly, Mr. Stebbing's work is intended as a text-book for the student in learning the elements of navigation rather than as a book of reference for the navigator, and as such it is admirably adapted. It is divided into the two portions of geo- and cœlo-navigation; the first of which does not require a knowledge of astronomical definitions nor of spherical trigonometry (with the exception of the part dealing with great circle sailing), and the second supposes an acquaintance with the more advanced mathematical methods. These two parts cover the whole range of practical education in seamanship. In Chapters XVI., XVII., and XVIII., Mr. Stebbing collects together all the more important problems in theoretical astronomy that have a bearing on nautical matters. As a text-book its value is much increased by the number of numerical examples that are scattered through the text. The definitions also, both nautical and astronomical, are printed in italics, an invaluable aid to the memory. It also possesses the indispensable feature of a book of reference in a complete and accurate index. In brief, it is in all respects an admirably devised and thoroughly well executed text-book. We notice one slight erratum not included in the list on page 328. On page 217 it is the arc H a, which measures the angle Z O S—the sun's zenith distance—not the arc H A, which is a quadrant of the circle.

SHORT NOTICES.

The Amateur Observer's Almanack, 1897. By Arthur Mee, F.R.A.S. (Arthur Mee, 41, Hamilton Street, Cardiff.) 6d. Mr. Mee has certainly compiled a vast amount of useful data, from the best sources, on a single card, about sixteen inches by twelve inches in size, suited for hanging on the wall. For amateur astronomers it is about the best sixpennyworth we have seen in the form of a chart The constellations visible in our latitude are indicated for the entire year, and the planets, as well as the sun and moon, are timed as to their risings and settings, etc., etc. All the astronomical signs, distances of celestial objects, etc., find a place, and even the best books for beginners are suggested. It would be a great improvement to have all the matters more carefully printed on a larger and stouter sheet, should the almanack survive another year.

Practical Work in Physics. By W. G. Woollcombe, M.A., B.Sc. Part III. (Clarendon Press.) 3s. Illustrated. The main feature of all Mr. Woollcombe's books on practical physics for schools and colleges is to provide a maximum of experimental illustration at a minimum of outlay in the way of apparatus. In this book the author deals with light and sound, and it is surprising how much real work may be done, as here indicated, by the aid of a quite inexpensive outfit. It may be remarked, however, that the book itself, considering its size (ninety-six pages), and probable cost of production, is very dear.

Artistic Landscape Photography. By A. H. Wall. (Percy Lund & Co.) Illustrated. There is plenty of information in this book on the possibilities of the amalgamation, so to speak, of artistic feeling with the purely mechanical operations in photography; but it is more than likely that the author's ideal will never be realized, for, judging from the illustrations shown, which are admirable in their way, it is not too much to say that most photographers can produce equally good pictures by the exercise of common sense in the choice of subjects, and discretion in the selection of points of view. However, the work may prove useful to those who desire to excel in the art.

Rocks and Minerals. By J. W. Tutt. (George Gill & Sons.) 1s. Illustrated. As a handy class book for object lessons in elementary schools, Mr. Tutt's little volume is well suited. At the beginning of each lesson a list of specimens is given, the method of teaching being much the same as that which is put forward in the late Dr. Guthrie's "First Book of Knowledge." Blackboard notes for the teacher's use are appended.

Insects and Spiders. This book forms Part II. of the above work (1s.), about which we have nothing more to say, save that both books are admirable in their way.

The Photogram, January Number, has made another innovation which adds to the value of this excellent monthly *résumé* of all that is useful to those who take an interest in photography. It has been changed from a twenty-four to a thirty-two page magazine, the larger type now used being much more in harmony with the fine engravings, from an artistic point of view, and far more inviting to the general reader than heretofore.

Messrs. Pastorelli & Rapkin have sent us a specimen of the "Wilson" dial rain gauge, which automatically registers the rainfall, in inches, on a clock-like disc. A bucket having a partition in the middle is centred on a horizontal axis, and the rain from the receiver draining into the bucket, first one half and then the other, causes the bucket to rock or tilt on its axis, and this movement through a vertical lever actuates a ratchet wheel, which in its turn communicates motion to the hands on the dial plate, which register to the $\frac{1}{100}$th of an inch. The device is very ingenious. The new patent vertical self-registering thermometer is also worthy of notice. Of course, in the old arrangement, where the thermometer was disposed horizontally, the fluid was liable to separate; but inconveniences arising from such a cause are obviously eliminated in this new form of instrument.

We are pleased to note the steady accession of the latest improvements in scientific apparatus to Messrs. Ross's handsome catalogues. All things optical and photographic turned out by this firm may be relied upon for excellence of performance, rational price, and durability. Among their latest additions are the "Eclipse" series of microscopes, the chief virtue of which, it would appear, is that they maintain absolute stability when used at any angle; the new patent science lantern specially designed for scientific demonstration, which can be used for ordinary projection or vertically, the change of position occupying only a few seconds; and the patent Ross-Hepworth arc lamp, combining all the desired features in this apparatus. The lenses, optical and photographic, are of worldwide repute. Among the latter, the Ross-Zeiss and Ross-Goerz anastigmatic, double and convertible anastigmatic, and telephoto types, merit special attention. Of course, it is impossible to do more than indicate a few out of the many excellent things figured in the pages of the several catalogues, and it will therefore suffice to add that this optical firm apparently take pride in doing everything well connected therewith.

We have received from Messrs. John Wheldon & Co. a very comprehensive catalogue of second-hand scientific books and works on natural history.

Letters.

[The Editors do not hold themselves responsible for the opinions or statements of correspondents.]

UNDERGROUND CAVITIES AND STREAMS IN IRELAND.

To the Editors of KNOWLEDGE.

SIRS,—The recent earthquake in England and the moving bog in Kerry may call attention to the extent to which the soil is undermined with cavities in various parts of the country. I spent a good part of my time for some years in, I believe, the most extensive district of this kind in Ireland, and though English readers are probably aware of its existence, they may not be cognizant of its extent. It stretches, I believe, almost the whole way from Westport to Gort, thus crossing a great part of the counties of Mayo and Galway. I do not, however, know the end of it next Gort, and shall commence with the river at Turloughmore or Claregalway, not far from Tuam. A turlough is a piece of land which forms a lake in winter—or, at least, part of the winter—while it is often good grass land in summer. But some of the Galway turloughs fill up with water and become dry again far too rapidly for the surrounding rainfall to account for. The water evidently enters and leaves by subterranean channels, and its presence or absence probably depends on the level of some neighbouring lake or river. These turloughs are often of considerable extent. But Turloughmore is a turlough no longer, a channel having been cut through a hill to allow the water to run off. The undermining of the soil shows itself in another shape. Not a drop of water runs through that channel in summer. The river—a good trout stream—sinks into the earth, and rises again, perhaps, two miles below. But it does not sink at once. First, on a day that I followed it in summer, down from Corofin, I heard a little waterfall close to the bank, and found that a part of the water was leaving the bed of the river and disappearing through a crevice in the limestone rock. A little further on I came to two or three little whirlpools caused by the water sinking in the middle of the stream, and then what was left seemed to run into a loose stone wall and disappear.

Going a little further west there is a little river in the village of Headford. It rises a very short distance from the village and is evidently supplied by underground water, but where it comes from I could not ascertain. The Black River, from its vicinity, seems most probable, but I could not find that its water was diminished. Possibly the Headford stream is a part of the Turloughmore River, or else supplied by an intervening lake. Passing through Headford we come to the Black River. A considerable part of this river sinks a short distance below Shrule, and rises again in two distinct streams at the distance of, perhaps, half a mile. Both streams run back to the original river, the bed of which is never completely dry. Before reaching Cong we reach another little stream at Douagh, or Cross, which exhibits the same phenomenon of partial sinking and rising again; but a short distance below the bridge over this stream there is a rise of water which seems at least as likely to come from Lough Mask as from the upper waters of the stream itself. If it comes from Lough Mask, its underground course can hardly be less than five miles.

The district between Lough Corrib and Lough Mask, especially about the village of Cong, is known to many tourists for its underground waters. In summer not a single drop of water travels the whole distance between the two lakes above ground, yet the river which reaches the lower lake, through Lord Ardilaun's demesne of Ashford, is a large one. This river may be said to rise in the village of Cong, the water being supplied by Lough Mask; but even below the village the water may be noticed sinking and rising again in the bed of the river. Less than a mile above Cong is the Holy Well, which runs dry when Lough Mask is low; and the course of the underground water from this down to Cong can be plainly traced, the rushing of the water below being sometimes audible, while at others it rises to the surface and forms a stream; and in one place there is a second small lake, which, being

at a lower level than the Holy Well, never runs dry. However, the main body of the river does not appear to travel by this path, and is probably more deeply buried in the earth. In winter a river runs the entire distance between the lakes, but in summer the channel (part of which was, I believe, intended to be a canal) presents very peculiar features. While the water at times sinks, at other times it comes in again, and instead of rising from the bottom it sometimes enters at the side at above the level of the stream, making a kind of little waterfall. It is but a short distance above Cong that the last portion of this stream disappears. The canal to which I referred was abandoned on account of the difficulty of making it staunch. The water would leave the channel and

Stream running from under the Rock, near Castlebar.

then burst in again, sometimes from the bottom and sometimes from the sides. A specimen of this can still be seen in the village of Cong, or, at least, could when I was last there. There are three places near Cong—two of them in Ashford demesne—to which visitors can descend to a considerable depth to see the underground streams. The third, known as the Pigeonhole, is the largest, and the underground cavity can be followed for a considerable distance. But when the level of Lough Mask is considerably raised in winter, new features present themselves. Streams suddenly burst up in the dry lands on the side of the hill between Cong and Douagh, and after running for some time with considerable force—pulling down any of the loose stone walls that come in their way—they disappear again. One of the largest of the streams whose disappearance I noticed in this way, rushed into what was called a water-hole—a small hollow where water remained throughout the year, and the cattle used to drink. I suspect that the bottom of this water-hole communicated with Lough Mask, and that a fissure at a somewhat higher level led to Lough Corrib. The ground where these outbursts took place lay so high that the water must have come direct from Lough Mask—or, at all events, from a part of the intervening river nearly on the level of the lake—and the distance travelled by the underground stream was probably not less than three miles. Yet the water never flowed in these channels for more than two or three days at a time, and it was only of a very wet winter that it flowed there at all. The peasants spoke of the direction of the wind as affecting it, but I think this could hardly be the case.

I shall now pass on to the other extremity of the district—Aylemore, near Westport. The river at Aylemore runs for about two miles underground, and then rises again and continues into Lough Mask, from which it issues in the manner already described. Aylemore struck me so much, and seemed so little known, that I got some photographs of it taken. The stream runs straight at a steep, rocky, hill—a limestone hill bounding the limestone district in that direction—its bed sinking as it approaches, and then it dips under. Plainly, however, the fissures are not very large. On the day that I visited Aylemore there had been a recent flood, whose limits were marked by some hay that had been carried away by the current. Close to the limestone ridge the hay-line could not, I think, have been less than seventy feet above the bed of the stream, which probably had not been raised ten feet by the flood somewhat higher up. The channels in the rock had evidently been too constricted to carry away the water, and a little lake had formed for the time being. But it had quite disappeared when I saw it, and the stream ran under the rock with a fairly rapid current.

The whole of this district must be scooped and caverned to an immense extent, yet I never heard of anything like the shock of an earthquake. Probably the caverns are not far enough below the surface for that purpose, and that if one fell in the shock would only be felt for a few hundred yards, which, in a sparsely populated district, might remain quite unnoticed. W. H. S. MONCK.

LUNAR RAINBOWS.

To the Editors of KNOWLEDGE.

SIRS,—The September Number of KNOWLEDGE has lately come to hand, and I have read with interest your correspondent, Mr. Sair's letter from Bhamo. At the beginning of 1890 I saw a lunar rainbow at Ponta Delgada, St. Michael's, Azores. The colours could not be distinguished—only a whitish band. In 1893 I saw another lunar rainbow at Para, as I was looking out over the Amazon, and in this the colours could be distinguished. About the same time I saw a triple sun's rainbow, the colours being distinct in the first two, but the third was like the lunar rainbow at St. Michael's—simply a whitish band. I do not know if these phenomena are common in the tropics, and should be glad if you could enlighten me.

Manaos, River Amazon. ERIC H. JACKSON.

[Lunar rainbows are necessarily rather rare phenomena, but are probably as often witnessed here, by those who look for them, as in the tropics.—E. WALTER MAUNDER.]

BACILLUS IN COAL.

To the Editors of KNOWLEDGE.

SIRS,—It is, perhaps, unnecessary for me to remind readers of KNOWLEDGE that the application of the microscope to geology has vastly enlarged the borders of that science, and that one of its most recent results is to show us the existence of the bacillus in coal. However, a French

savant, M. Renault, was examining thin sections of coal under the microscope, and noticed certain clear bands in the dark substance of the coal. On looking closer he found that these were made up of minute bodies in the characteristic groups and clusters of micrococci and bacilli. Thus we find that the bacillus, which has only been known to science for some two hundred years, has in reality existed as far back as the carboniferous epoch. This is interesting in itself, and raises the further question whether bacterial action may not have been an agent in the formation of coal. In favour of this view we have the fact that the number of bacteria in coal exceeds that in vegetation preserved by silica or carbonate of lime, and that the species are fewer. Also that they are not coloured like the coal, but appear as clear bands. On the other hand, we know that the general result of bacterial action is the complete destruction of vegetable fibre. If, then, the bacillus has been an agent in the formation of coal, we must suppose the action to have been arrested at different stages for the different sorts of coal.

Corbridge-on-Tyne. G. W. BULMAN.

STAR SYSTEMS.

To the Editors of KNOWLEDGE.

SIRS,—It is not easy to follow Mr. Monck's argument in his letter, page 275. I take it that he is seeking to throw light on the discussion, in your October and November Numbers, as to the correctness of the late R. A. Proctor's theory that most of the bright stars in Charles's Wain form not only an apparent group but a real one, and that they are drifting together through space. As Mr. Monck himself points out, the case of stars in widely separated portions of the sky is a totally different one, and throws no light on the question; so it does not appear why he refers to such cases. The question is, Is the proper motion of the stars under consideration in sufficient agreement, and is their parallax sufficiently imperfectly known, to afford a probability that they are travelling together? Judging by the drawing on page 251, must we not answer the first part of the question in the affirmative—at least as regards γ, δ, ε, and ζ? Perhaps Mr. Monck can answer as to the second point. We must bear in mind, too, that while common drift gives some presumption in favour of a connected system, motions in different directions are no proof of the absence of such connection—at least, unless continued for a long period; for it is quite possible that a star may be revolving in a wide orbit round a dark star, in which case one needs to know the proper motion of the centre of gravity of the pair.

Sunderland, T. W. BACKHOUSE.
January 18th, 1897.

THE LEAF-CUTTER BEE.

To the Editors of KNOWLEDGE.

SIRS,—I have read with considerable amusement Mr. Fred. Enock's letter, in which he endeavours to prove that my article on the leaf-cutting bee is inaccurate. Mr. Enock's corrections, however, are unfortunately distinctly incorrect, as I am able to testify, both from personal observation and the authority of such well-known scientific men as Prof. W. S. Dallas, F.L.S.; Prof. F. V. Theobald, M.A., F.E.S.; and my father, the late Prof. P. M. Duncan, F.R.S., F.L.S.

Mr. Enock's first statement—"As soon as the leaf-cutter bee has made her burrow, she flies off and selects a rose-bush of the 'tea' type"—is most misleading, as it gives the reader the idea that the bee confines herself solely to this species of rose-bush for the material with which she forms her cells. I have proved by personal observation that these bees do not confine themselves to one species of rose-bush. Prof. W. S. Dallas states: "The rose, laburnum, and garden acacia seem to be the favourite trees with these insects"; and again, Prof. F. V. Theobald says the bees "line the tunnels with pieces of rose and *other* leaves."

Mr. Enock then goes on to say the bee "first cuts a circular piece somewhat larger than the diameter of the burrow, into which she fits it at the bottom." This is incorrect. The first piece of leaf used is oblong and narrower at one end, and this narrow end is folded under to form the base of the cell; the succeeding six or seven pieces being similar in shape, varying slightly in size. I have carefully examined several cells (some of which I have in my possession at the present time), and have never found as many as twelve of these oblong leaves, the usual number being seven or eight.

I cannot imagine on what authority Mr. Enock asserts that "as many as a dozen circular pieces" are used to close the mouth of the first cell, when it is an acknowledged fact that the maximum number of circular pieces is four, but usually only three are found. These circular pieces do not form the foundation of the next cell, each cell being complete in itself.

The bee-bread, which Mr. Enock describes as a "delicious pudding," is actually a dark, compact mass, emitting a fœtid odour.

FRANCIS M. DUNCAN.
3, Chesterton Villas, Warwick Road, Redhill.
January 12th, 1897.

THE ZODIACAL LIGHT.

By Lieut.-Col. E. E. MARKWICK, F.R.A.S.

THE season when this phenomenon is visible after sunset is now approaching, and it may be interesting to take stock of what we know about it, which, after all, seems to be surprisingly little. It is generally dismissed in the text-books with a pretty short notice, and sometimes is not mentioned at all. Although it can hardly be called a popular object in the sense that Mars or Jupiter is, still there must have been a great number of observations made of it at different times, and one looks for a corresponding definite advance in our knowledge of its interior economy. But the conditions of its visibility in our latitude render exact observation extremely difficult. Like the inferior planets, Mercury and Venus, it is seldom, if ever, seen more than three or four hours after sunset or before sunrise, and cannot be observed on the meridian. Again, its tenuous and ethereal character render it a difficult matter to note definite particulars of its shape, size, or position. In these respects no instrument is of the slightest service; but the observer should be one with a keen eye, which can take in a large area of the sky, and is quick in apprehending differences in brightness of particular areas. No telescope can do this, and, even with a binocular, the field of view commanded is far too small. The best way is to sweep the eye rapidly right and left, up and down—that wonderful faculty of "averted vision" assisting to note very faint degrees of light.

My own experience, based on some sixteen years of observation in different latitudes, is that provided one has a clear country horizon remote from the glare of towns or electric lights, with a dark clear sky in January or February, there is no difficulty to the ordinary observer in England in detecting, soon after sunset, the pearly cone

of the zodiacal light sloping upwards from the sun's place. The boundaries are generally ill-defined, and the apex has usually to be imagined more or less, so exceedingly delicate is the glow towards the extremity of the cone. Guillemin, in "The Heavens," has a very delicate plate of it, as seen in Japan. In this picture it looks fainter than it is sometimes seen in England.

For all practical purposes the axis coincides with the plane of the ecliptic.

An open horizon has a good deal to do with its visibility. For years I looked carefully for it in England without success, and I think the reason was that trees and other prominent objects, dark against the western sky, must have put my eye out of focus for the faint light. There are some who have not the power or capacity for this class of seeing, and I have before now, when in southern latitudes, pointed it out, quite blazing, to a friend, who, however, could make nothing of it, although it was literally staring him in the face.

Humboldt, in his "Cosmos," has some most interesting remarks on the subject, the more so as they are based on personal observation and considerable literary research.

My first observation of zodiacal light was in Natal, where it was at once palpable. It was in the dry, clear air of the uplands of South Africa, however, that it was seen to the greatest perfection; while in the Transvaal and in Bechuanaland the light was almost blazing—at least, it seemed so to an eye accustomed to astronomical phenomena, not to bonfires. Unless one has been in these circumstances of latitude and climate, it is impossible to imagine what an exquisitely delicate and ethereal object the light is. For there one has great advantages, notably in the transparency of the atmosphere, and the fact that the light is perpendicular, or nearly so, to the horizon. It is extremely difficult, when it slopes at the angle it does in England, to judge of the relative sharpness of the margins: a point which I have studied of late in connection with Dr. Veeder's theory of its duplicity. At Gibraltar, whence I write, it is often most beautifully seen as a whole, and Humboldt refers to its greater intensity in Spain, on the coast of Valencia, etc. From our coign of vantage we have the privilege of looking across the Bay of Gibraltar, with the range of hills beyond Algeciras in the distance, and, except for occasional shipping, this view is free from artificial illumination or glare.

Humboldt thinks that the zodiacal light was unknown to, or at least not mentioned by, the ancients. The word *trabes*, occurring in Pliny, which some consider means the phenomenon in question, refers to meteors, bolides, and comets. According to Humboldt, it is first explicitly described by Childrey, chaplain to Lord Henry Somerset, in his "Britannia Baconia."

Dom. Cassini was the first to investigate the phenomenon in its relations in space, in 1683. Cassini, Humboldt says, maintained that a phenomenon observed by him at Bologna, also by Chardin in Persia, in 1668, was the zodiacal light, but that really this was the tail of the comet of 1683, whose head was at the time below the horizon. This calls to mind the great comet of 1882, which I first saw after perihelion in the beautiful sky of Natal about 4 A.M. The head was below the horizon, and the tail sloped upwards for many degrees—a most extraordinary vision. Never can that supremely beautiful sight be forgotten, as the comet majestically rose and displayed himself, surrounded by a gauze veil more ethereal than any bride's.

But no one could for a moment mistake the comet of 1882 for the zodiacal light. On the contrary, the view of the great comet of 1880, which I also got in Natal, might have been easily confounded with it, on account of its exceeding faintness and delicacy.

Humboldt considers that a remarkable light seen in 1509 for forty nights consecutively, in the elevated plains of Mexico, was the zodiacal light. He found a notice of this light in an ancient Aztec MS., preserved in the Royal Library of Paris.

Humboldt proceeds to inquire into the nature of the zodiacal light, and considers "a very compressed annulus of nebulous matter revolving freely in space, between the orbits of Venus and Mars, as the material cause" of it. Coming to more modern times, Sir J. Herschel thinks it is "that medium which resists the motion of comets, loaded, perhaps, with millions of tails of these bodies." Still later, the idea is that it consists of myriads of small meteors, each revolving round the sun in its own path, the light reflected from which impresses itself on our eyes as the zodiacal light. This is the opinion of Prof. Pickering, who, in Vol. XIX. of "The Annals of Harvard College Observatory," has discussed many observations with his usual acumen.

It would seem certain from the observed angular distance of the apex from the sun that these meteors extend beyond the earth's orbit; and as the light lies in, or very close to, the ecliptic, we must be perpetually cutting through them as we revolve round the sun. Do we see in our atmosphere the falling meteors which have originally formed a portion of the zodiacal light? We are of opinion this question can only be settled when that of the relation of comets to meteors is settled, and we know what a dubious matter that is in its purely physical aspect.

Dr. Veeder, of New York, considers that the zodiacal light "does not conform to the plane of the earth's orbit, but to that of the equator of the body which it surrounds, which in this case is the sun itself. As viewed from the earth, these coronal extensions are at times foreshortened, and at times opened out, so as to become more plainly visible. In the spring months, the south pole of the sun is inclined towards the earth, so that the latter is almost exactly in the heliocentric zenith of the southern sunspot belt and coronal extension. Consequently the particles composing this extension are in a direct line between sun and earth, and, shining as they do by reflected light, like the new moon, they become almost invisible. Coincidently the coronal extension overlying the northern sunspot belt is opened out to its widest extent, and reflects more light earthward than at any other time. Hence, if these extensions become visible as the zodiacal light, the southern edge at this season should be the more sharply defined, and more exactly included within the plane of the ecliptic, because of the lack of illumination described; and the northern edge, on the other hand, should shade off very gradually, departing more widely from the plane of the ecliptic, and this is precisely what has been found to be the case."

My own observations made at Gibraltar most certainly support this view.* It has also been observed by Cassini and others. Dr. Veeder further observes that it is probable "that these coronal extensions serve as conductors of electrical impulses," and are therefore connected with the appearance of auroræ.

The question of the variability of the zodiacal light has been much discussed. Humboldt says: "I have occasionally been astonished, in the tropical climates of South America, to observe the variable intensity of the zodiacal light. As I passed the nights, during many months, in the open air, on the shores of rivers and llanos, I enjoyed ample

* See *English Mechanic*, No. 1625.

opportunities of carefully examining the phenomenon. When the zodiacal light had been most intense, I have observed that it would be perceptibly weakened for a few minutes, until it again suddenly shone forth in full brilliancy. In some few instances I have thought that I could perceive, not exactly a reddish coloration, nor the lower portion darkened in an arc-like form, nor even a scintillation—as Mairan affirms he has observed—but a kind of flickering and wavering of the light." These rapid apparent changes, however, he thinks, may be partly due to causes acting in the upper strata of our atmosphere.

Olbers convinced himself "that this light is very different in different years, often for several successive years being very bright and diffused, whilst in other years it is scarcely perceptible." This, of course, is a different sort of variation from the temporary or momentary changes just mentioned. Some modern observers think it decidedly variable in the way mentioned by Olbers—that is, more brilliant on some occasions than on others. But we must bear in mind two things in considering this question. First: as seen in England the total apparent length of the cone decreases gradually as the season of visibility goes on. Thus, for the evening apparition the length as observed in March and April is nearly always markedly less than when seen in January and February.* Hence, because the length of the cone appears different as seen at dates separated by an interval of (say) a fortnight, it is not necessarily to be inferred that the brilliancy has changed in that interval of time. Second: we all know how after a spell of dull or wet weather an unexpectedly clear night suddenly turns up. On the last occasion of a clear but "poor" night, the zodiacal light perhaps looked poor too. Now, on the *very* clear evening, it is seen under fine conditions, and naturally the finer and more delicate parts stand out clearly. But this is not variability. We cannot focus our sight on to this delicate object as on a variable star, and the circumstances are such as do not admit of the application of exact photometry to the case. To decide this question we need a regular series of systematic observations made in some clear and serene sky, like that of Peru or the Transvaal, night after night and year after year. Such observations should give, according to a fixed method, the length and breadth; also the brightness, say at certain fixed altitudes, as compared with the Milky Way. It is only from such a record that the question of variability can be settled. Very possibly, changes in the density of different parts of the zodiacal meteors or cosmic dust may take place from time to time, and consequently changes in brightness. But I do not think that so far they have been fairly proven.

Some observers have noted a ruddy tint, but I confess that I have never detected this.

Good observers, like Admiral Smyth, acknowledge many disappointments of not catching it; and to anyone who has not yet seen the light, but wishes to do so, I would offer the following suggestions:—Time, middle of January to middle of March; locality, remote from any large town or collections of lights. From some of the breezy commons and downs of Surrey or Sussex, well to the south of the metropolis and free from trees, one can command a grand sweep of sky. Better still if the observer has a sea horizon to the west, for then, provided there is no shipping, he may be absolutely certain that no artificial glare exists. Choose a brilliant evening such as sometimes comes after heavy rain. There must be no trace whatever of moonlight, which blots out our faint subject. Keep on the look-out, say, from a quarter of an hour after sunset. Do not strain the sight by looking fixedly at a star, or in one place. Cast the eye occasionally over the western sky towards the horizon, and with the above circumstances favourable you should have no difficulty in "catching" the phenomenon and "holding" it, too. I am not quite prepared to say whether near-sighted persons would be handicapped in this search. Possibly spectacles may in some way impede vision in sweeping over a large area of the sky. There *must* be a slight loss of light, even through one lens only. Personally, I am blessed at present with a long sight, which does not need any assistance in the way of glasses. When once seen, it is comparatively easy to see it again another night, as we then know what sort of a thing it is we are looking for.

It is curious that the zodiacal light has not been seen during a total eclipse of the sun, and it would therefore seem that its light is decidedly inferior to that of the corona. At the same time, in such a consideration one must not omit to take account of the vast area of illuminated earth and sky which surrounds the moon's shadow cone. The darkness of an eclipse is not that of night.

Would an observer from Neptune, supposing he could do without any atmosphere himself, see the sun as a "nebulous star," with the zodiacal light extending on either side like a delicate comet? Very probably—with many a comet ploughing through it, which our own atmospheric veil prevents us by its brilliant glare from seeing. Take as an instance the comet seen close against the sun during the total solar eclipse visible in Egypt in 1882.

There are two other phenomena connected with the zodiacal light, viz., the *gegenschein*, or counter glow, and the zodiacal band. The first is a faint patch of light seen very nearly opposite the sun's place; the other is a prolongation of the zodiacal light to the *gegenschein*. Both these are excessively delicate phenomena and require the finest sight and sky. Although I consider I have a good eye, I have never seen either. Even Prof. Pickering can only say that "the evidence for the actual existence of some light opposite the sun becomes tolerably strong." Still, there can be but little doubt of the existence of the *gegenschein* from the observations of Brorsen, Schmidt, Heis, Backhouse, Lewis, Barnard, and others. But the ordinary observer can hardly hope to detect this or the zodiacal band.

* *See* observations of Prof. Pereira and self in *Journal Brit. Ast. Assoc.*, Vol. V., pp. 361, 421.

EVIDENCE OF THE EVOLUTION OF STELLAR SYSTEMS.

By ISAAC ROBERTS, D.Sc., F.R.S.

THE answers which to me appear to be relevant to the questions propounded in the first part of this communication, will be found by the correlation of the annexed photographs of four spiral nebulæ with the four photographs of stars which were given in the last number of KNOWLEDGE.

No. 1 is of the spiral nebula in Pisces, R.A. 1h. 31m., Decl. 15° 15′ north. Exposure, 3h. 40m. on the 9th December, 1893. Scale, one millimètre equals twelve seconds of arc.

No. 2, spiral nebula in Ursa Major, R.A. 13h. 59m., Decl. 55° 10′ north, Exposure, 3h. 20m. on the 30th May, 1892. Scale, one millimètre equals twelve seconds of arc.

XUM

No. 3, spiral nebula in Ursa Major, R.A. 10h. 12m., Decl. 41° 57′ north. Exposure, 4h. on the 14th April, 1893. Scale, one millimètre equals twelve seconds of arc.

No. 4, spiral nebula in Canes Venatici, R.A. 13h. 25m., Decl. 47° 45′ north. Exposure, 2h. 55m. on the 15th May, 1896. Scale, one millimètre equals twelve seconds of arc.

It will be seen on examination of these photographs that the nebulous matter in the spirals is broken up into stars and starlike loci, and these vary in brightness between the light of stars of about the seventeenth magnitude and that of about the thirteenth magnitude. The bright stars are as well defined round their margins as are any other stars in the sky, whilst the fainter ones are nebulous and not well defined round their margins; and those that differ but little in brightness from the nebulosity in which they are immersed have generally margins more or less undefined.

Every spiral nebula that I have photographed has a stellar nucleus surrounded by dense nebulosity in its centre of revolution, and around that centre the nebulous convolutions and the stars involved in them are symmetrically arranged. The records of these features are now so numerous and accordant that they cannot be attributed to accidental or fortuitous causes. They must be referred to the action of known physical causes of which we have ample evidence.

Up to this point we have directed attention to the photographic records, which prove with absolute certainty —for they are unaffected by personal bias or error—the existence, the forms, and the structures of these nebulæ. We can also measure the phases, the structural details, the diameters, and the relative distances apart of the stars involved in them; but we cannot determine their distances from the earth for the reason that no measurable parallax is presented by them. That their distances from the earth are very great is also proved by the fact that I have not been able to discover any obvious change to have taken place, during intervals of from four to seven years, in the stars or in the nebulosity depicted upon those photographs which I have been enabled to compare with one another. It is true that the comparisons referred to are not reliable for distances of less than about three seconds of arc by measurements on the negatives.

We shall now turn a little aside from the solid path of positive evidence, to make some inferences from it in answer to the questions: Of what materials are the spiral nebulæ composed? Whence the source of the vortical motion which evidently has produced their forms? We need not proceed far into the domain of speculation to seek an answer, for we have the evidence of Sir William Herschel, of Sir John Herschel, of Lord Rosse, and since their time the evidence of many other competent observers who possessed large optical appliances, by which they discovered that in many regions of the sky extensive clouds of nebulous matter exist. Sir William Herschel alone has recorded the positions of fifty-two such regions, and within the past ten years photographs have been taken which confirmed the truth of those eye observations, as well as placed before our eyes accurate structural delineations and definitions of the boundaries of some of those nebulous areas.

The material in space out of which symmetrical nebulæ may be condensed has been proved to be both extensive and widely spread; but whence the vortical force by which the spiral nebulæ have been formed?

Considerable evidence from the past is available by which we feel assured that collisions have taken place between bodies in space—*Nova Aurigæ* and *Nova Andromedæ* are recent examples. We know also that every star, planet, nebula, comet, or other object discovered in space is in rapid motion of translation, and that the motions are—with the exception of those stars physically connected—in diverse directions and apparently not controlled by a common central governing force.

In the case of several of the nebulæ the photographs show them to be bodies of a lenticular form, because they are viewed edgewise, and are either spiral, ellipsoidal, or circular when viewed full-face. They are also presented to us at all angles between these extremes, and of course every angle of view presents them with differing outlines.

There are also nebulæ which have not yet assumed a regular or a geometrical figure: of such is the great nebula in *Orion*, and the *Crab* nebula *M.* 1 *Tauri*. These are probably nebulosities in a less advanced stage of development than those which have geometrical outlines, and there can be no reasonable doubt that there exists in various parts of space nebulosities which may be classified under the divisions following:—

1. Vast areas of cloudlike matter; gaseous, and probably of discrete solid particles intermixed.
2. Smaller areas of matter undergoing the process of condensation and segregation into more regular forms.
3. Spiral nebulæ in various stages of condensation and of aggregation.
4. Elliptic nebulæ.
5. Globular nebulæ.

In the three classes last named there is clear evidence, observable on every photograph which has been taken, that condensations into stars, or into starlike forms, of the nebulous matter is now taking place within them.

Prof. Norman Lockyer, in his "Meteoritic Hypothesis," points out that collisions of meteorites in a swarm would produce luminous nebulosity; so also would collisions between swarms of meteorites produce all the conditions requisite to account for the vortical motions and the distributions of the nebulosity in the spiral nebulæ; the starlike aggregations of the nebulous and meteoric matter subsequently taking place, as the photographs show, in the convolutions.

Spiral nebulæ might also be the result of collisions between globular bodies such as the earth. But we will now proceed to point out the apparent relationship between the curves and lines of stars shown upon the four photographs which accompany the first part of this communication, with the curves of stars which are immersed in the convolutions of the spiral nebulæ as shown on the accompanying photographs. The subject is not one for argument, but for observation and correlation of the photographs; and I will assume that the similarity of the curves of stars respectively upon them is obvious to sight. A little further consideration will also make it clear to us that if we could view these nebulæ edgewise, the stars involved in the convolutions would appear as approximately straight lines; and when the whole of the nebulosity has been absorbed by the stars, they will in all respects resemble and emit light like the finished stars that we see by the photographs actually existing in space.

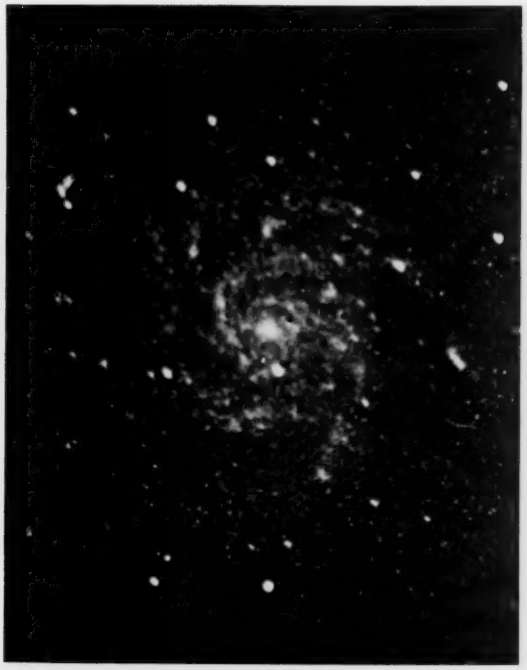
If the visible evidence which is now before us is here correctly interpreted, we must accept as a reasonable ground for belief that stellar systems are now in process of evolution out of nebulous and probably meteoric matter; and that it is only a question of time when changes in the structures, and in the several phases of the nebulæ and of the stars, will be made evident on comparison of photographs which have been taken with long intervals of years between them.

PHOTOGRAPHS OF SPIRAL NEBULÆ IN THE CONSTELLATIONS PISCES, URSA MAJOR, AND CANES VENATICI.

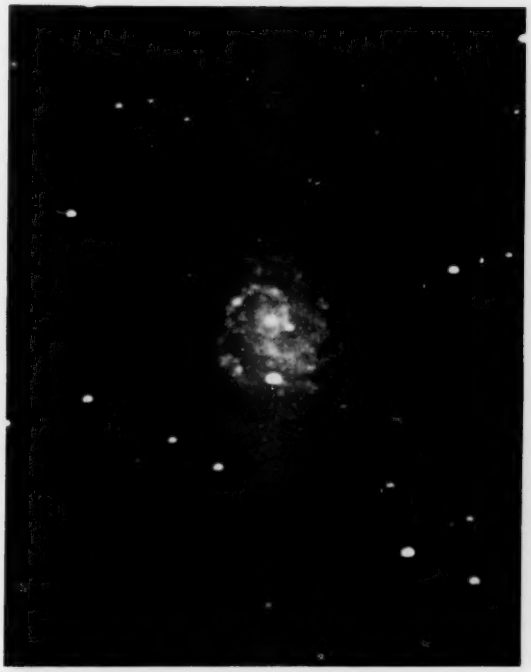
By ISAAC ROBERTS, D.Sc., F.R.S.

1.

2.



3.



4.

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PERIODICAL COMETS DUE IN 1897.

By W. T. LYNN, B.A., F.R.A.S.

DR. SPITALER (now of the Imperial Observatory at Prague) discovered a faint comet at Vienna on the 17th of November, 1890. As it was found to be moving in an elliptic orbit with a period of less than six and a half years, he has calculated that it should return to perihelion on the 11th of March in the present year. But it was nearest the earth in September, and as it has not been seen, we must conclude that it is too faint to be visible at this return.

Two other periodical comets will be due in perihelion during the forthcoming spring; that of D'Arrest, which was discovered at Leipzig on the 27th of June, 1851, calculated to complete a revolution in six and a half years, and observed at appearances in 1857, 1870, 1877, and in 1890, when it passed its perihelion on the 16th of September; and that which was first discovered by Tempel in November, 1869, but its periodicity was not detected until after its rediscovery by Prof. Swift in October, 1880, in consequence of which it is usually known as Swift's comet. The period of the latter is only about five and a half years; but as it escaped observation in 1875, when it was not looked for, so also it did in 1884, when it was, though with small hope of seeing it, as it was unfavourably placed. It was, however, well observed at the last return, which took place in 1891; the perihelion passage took place on that occasion in the month of November, and another will be due in April or May next.

[It may not be out of place to add to Mr. Lynn's list of periodical comets expected this year the fact that the comet discovered by Mr. Perrine on December 9th, 1896, has now been found to be a comet of short period, six and a half years, and therefore, like the above, a member of the "Jupiter family." More interesting still, its elements closely resemble those of the lost comet of Biela in everything but the longitude of the perihelion.—E. WALTER MAUNDER.]

THE FACE OF THE SKY FOR FEBRUARY.

By HERBERT SADLER, F.R.A.S.

SPOTS still occasionally appear upon the solar disc. Conveniently observable minima of Algol occur at 9h. 59m. P.M. on the **7th**, at 6h. 48m. P.M. on the **10th**, and at 11h. 42m. P.M. on the **27th**.

Mercury is a morning star, but owing to his southern declination is not very well situated for observation. He rises on the **1st** at 6h. 22m. A.M., with a southern declination of 18° 22′ (at noon), and an apparent diameter of 9¼″. On the **11th** he rises at 6h. 11m. A.M., with a southern declination of 19° 39′, and an apparent diameter of 7⅓″. On the **21st** he rises at the same time, with a southern declination of 19° 0′, and an apparent diameter of 6½″. After this he approaches the Sun too closely to be visible. He describes a direct path through Sagittarius into Capricornus, and is at his greatest elongation (26½° W.) on the morning of the **16th**.

Venus is now becoming a very fine object in the evening sky. On the **1st** she sets at 9h. 11m. P.M., or nearly four and a half hours after the Sun, with a southern declination of 0° 15′, and an apparent diameter of 21″. On the **12th** she sets at 9h. 37m. P.M., with a northern declination of 5° 20′, and an apparent diameter of 23″. On the **19th** she sets at 9h. 53m. P.M., with a southern declination of 8° 45′, and an apparent diameter of 25″. On the **28th** she sets at 10h. 7m. P.M., with a northern declination of 12° 51′, and an apparent diameter of 28″. During the month she describes a direct path in Pisces.

Mars is an evening star, and is still well situated for observation. On the **1st** he sets at 4h. 24m. A.M., with a northern declination of 25¼°, and an apparent diameter of 11″, the phasis on the following limb amounting to about ¾″. On the **12th** he sets at 3h. 58m. A.M., with a northern declination of 25° 23′, and an apparent diameter of 9·9″. On the **19th** he sets at 3h. 41m. A.M., with a northern declination of 25° 31′, and an apparent diameter of 9¼″. On the **28th** he sets at 3h. 15m. A.M., with a northern declination of 25° 38′, and an apparent diameter of 8½″. During February he pursues a direct path in Taurus.

Jupiter is an evening star, and is now well situated for observation. He rises on the **1st** at 6h. 58m. P.M., with a northern declination of 9° 47′, and an apparent equatorial diameter of 44¾″. On the **12th** he rises at 6h. 5m. P.M., with a northern declination of 10° 16′, and an apparent diameter of 45¼″. On the **20th** he rises at 5h. 30m. P.M., with a northern declination of 10° 40′, and an apparent diameter of 45½″. On the **28th** he rises at 4h. 50m. P.M., with a northern declination of 11° 4′, and an apparent diameter of 45⅔″. During the month he describes a short retrograde path in Leo.

Both Saturn and Uranus are, for the purposes of the amateur observer, invisible.

Neptune is an evening star, setting on the **1st** at 8h. 18m., with a northern declination of 21° 28′, and an apparent diameter of 2·7″. On the **28th** he souths at about 6h. 30m. P.M.

There are no very well marked showers of shooting stars in February.

The Moon is new at 8h. 13m. P.M. on the **1st**; enters her last quarter at 7h. 25m. P.M. on the **9th**; is full at 10h. 11m. A.M. on the **17th**; and enters her last quarter at 3h. 44m. A.M. on the **24th**.

Chess Column.

By C. D. LOCOCK, B.A.Oxon.

Communications for this column should be addressed to C. D. LOCOCK, Burwash, Sussex, and posted on or before the 10th of each month.

Solutions of January Problems.

No. 1.

(W. Clugston.)

1. B to QR3, and mates next move.

It will be noticed that the second move is identical in every variation.

No. 2.

(J. T. Blakemore.)

Key-move.—1. Q × P.

If 1. . . . K to K4,	2. Q × Pch, etc.
1. . . . P × R,	2. Q × Pch, etc.
1. . . . P to K7,	2. R × P, etc.
1. . . . B × KBP,	2. B to Kt3ch, etc.
1. . . . B to K5,	2. Q to Q6 mate.
1. . . . Kt × P,	2. Q to B5 mate.
1. . . . Anything else,	2. Q × Pch, etc.

Nearly all our solvers have gone astray over this fine problem.

CORRECT SOLUTIONS of both problems received from Alpha, E. W. Brook, both of whom, however, overlook the defence, P to K7.

Of No. 1 only from G. G. Beazley, Rev. F. W. Quilter, D.D., W. H. Stead, J. M'Robert, E. C. Willis, Captain Forde, Sigma.

H. Le Jeune and A. P. Hyatt.—In No. 1, after 1. Kt moves, K moves, there is no mate, as the Bishop can cover.

Sigma and Captain Forde.—If (in No. 2) 1. Q to Ksq, Black can safely reply Kt to KB4.

A. P. Hyatt.—If 1. B to Kt3ch, K×B; 2. K to Kt5, R to R8, or P×R, and there is no mate.

M. Wiedhofft.—After 1. B to Kt3ch, K×B, 2. Q×P, Black may do anything except move the Bishop.

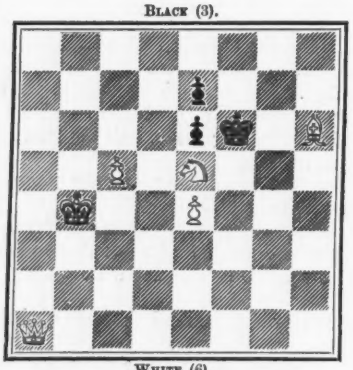
H. Le Jeune.—In No. 2, 1. B to B6 would allow Black to make almost any move which threatens a check, for White threatens nothing. Black, in fact, would win!

PROBLEMS.

By C. D. Locock.

No. 1.

BLACK (3).

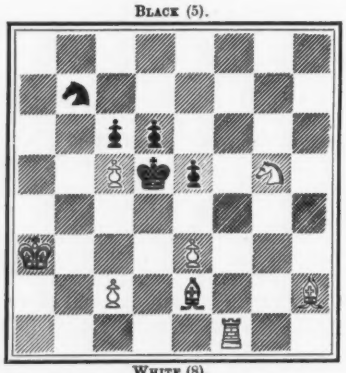


WHITE (6).

White mates in two moves.

No. 2.

BLACK (5).



WHITE (8).

White mates in two moves.

[The publication of these elementary editorial positions may be construed as a sign that our stock of problems by the readers of this column is again exhausted.]

CHESS INTELLIGENCE.

The Lasker-Steinitz championship match resulted, as was expected, in a decisive victory for Mr. Lasker—the score at the conclusion being, Lasker 10, Steinitz 2, drawn 5.

The two games lost by the winner were consecutive defeats at a time when final victory was assured, and are ascribed to ill-health. At any rate, they bear internal evidence that Mr. Lasker was not in his best form when they were played. The result of the match is decisive, and we imagine that it will be the last encounter between these opponents. Mr. Steinitz was without doubt, for a great many years, the finest player in the world, but he was ill-counselled not to retire when his powers showed signs of failing. No chess player can expect to be champion for more than twenty-one years.

The Craigside Tournament, under the joint auspices of the Counties' Chess Association and the Craigside Committee, took place at Llandudno during the week beginning January 4th. The score in Class I. was as follows:—G. H. Bellingham 8, A. Burn 7½, C. H. Sherrard 6, W. H. Gunston and E. MacDonald 5, E. O. Jones 4½, E. Jones-Bateman 4, Rev. J. Owen 3, Rev. A. B. Skipworth 2, A. Rutherford (retired) 0.

Mr. Bellingham's victory in such company is a very fine performance, and will, no doubt, secure him a place in the British team *v.* America this month. Mr. Sherrard was the strongest player in Kent while he resided in that county. Messrs. Jones and Owen, who have usually done so well in the Craigside tourneys, failed to sustain their reputations. The result of the handicap confirms that of the level tournament. Mr. Sherrard won one section with great ease, while Mr. Bellingham was again just half a point above Mr. Burn in the other section, all three, of course, playing from scratch.

In the Southern Counties' Chess Union, Surrey have scored decisive victories over both Kent and Sussex, and should be certain of retaining the cup.

A little tournament at Vienna lately resulted as follows:—Janowski 3½, Schlechter 3, Mieses and Winawer 2½, Marco 2, Albin 1½—just as one might expect. M. Janowski afterwards defeated Herr Winawer in a match by 5 games to 2.

KNOWLEDGE, PUBLISHED MONTHLY.

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